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PROGRAM

High Power Lasers - Science and Engineering

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High Power Lasers - Science and Engineering

Directors

Dr. Ram Kossowsky, President
Emerging Technologies, Inc., Pittsburgh, Pennsylvania, USA

Professor Miroslav Jelinek
Czech Academy of Science
Institute of Physics, Prague, Czech Republic

Dr. Robert Walter, Senior Scientist
W. J. Schafer Associates
Albuquerque, New Mexico, USA

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Program

High Power Lasers - Science and Engineering

SUNDAY, 16 July 1995

11:45	Bus 1 leaves Prague Airport
14:00	Registration Open
15:15	Bus 2 leaves Prague Airport
19:15	Welcome party
20:30	Dinner

MONDAY, 17 July 1995

08:00-09:00	Breakfast (First day, later than normal)
08:30-10:00	REGISTRATION, pay all bills.
	Session I : Opening
	Chairman: Prof. Miroslav Jelinek
10:00-10:15	Welcome, procedural discussions. Dr. Ram Kossowsky.
10:30-10:45	His Excellency, Igor Savič, Mayor of Karlovy Vary
10:45-11:00	Break
11:00-13:00	Prof. Alexander Manenkov: "History, current status and outlook for the future"
13:00-	Lunch
	Setup First Week Posters
	Session II : Laser Device Technology Overview
	Chairman: Dr. Keith Truesdell
16:30-18:30	Prof. Vladislav Moshkov: "Active media disturbances in high power gas lasers"
18:30-19:00	Discussion Period
19:00-19:40	
19:40-20:00	Discussion
20:15-	Dinner -

TUESDAY, 18 July 1995

07:00-08:30	Breakfast
	Chairman: Prof. Geoffrey Hogan
08:30-10:30	Dr. W. J. Witteman: "Characteristics of CO and CO_2 Lasers."
10:30-11:00	Discussion Period
11:00-11:30	Break
11:30-13:00	Contributed Papers, #4, 5, 6: Igor Baranov, Alexander Lavrov, Maxim Novgorod
13:00-	Lunch
	Chairman: Prof. Bernard Lacour
16:30-18:00	Dr. Keith Truesdell: "Fundamentals and Current Status of Iodine Lasers
18:00-18:30	Discussion period
18:30-20:00	Poster Sesssion
20:15-	Dinner

WEDNESDAY, 19 July 1995

07:00-08:30	Breakfast
	Chairman: Dr. Vladislav Moshkov
08:30-10:30	Prof. Geoffrey Hogan: "Fundamentals and Current Status of Metal Vapor Lasers"
10:30-11:00	Discussion Period
11:00-11:30	Break
11:30- 13:00	Contributed Papers, #9, 10 Viktor Tarasanko, Borislav Ivanov
13:15-	Lunch
14:15-	Excursion
20:30-	Dinner

THURSDAY, 20 July 1995

07:00-08:30	Breakfast
	Chairman: Prof. W. J. Wittman
08:30-10:30	Dr. Henry Brunet: "Fundamentals and Current Status of Excimer Lasers
10:30-11:00	Discussion Period
11:00-11:30	Break
11:30-13:00	Contributed Papers, #12, 13, 14 Thomas Nelson, Alexandru Hening, Kirill Prokhorov
13:15-	Lunch
	Chairman: Dr. Ram Kossowsky
16:30-18:00	Pannel Discussion - "Directions for Development - Power vs Wavelength"
18:00-18:30	Break
18:30- 20:00	Poster Session
20:15-	Dinner

FRIDAY, 21 July 1995

06:00-07:15	Breakfast
07:30:	Bus departs for trip to Prague: Karlstein Castle, Lunch, Check in Crystal Hotel in Prague, Guided Tour, Dinner at "U Flecu".

SATURDAY, 22 July 1995

7:30- 0830	Breakfast, Crystal Hotel
09:00-	Drive to Town. Free time
17:15-	Bus leaves Prague
20:30-	Dinner

SUNDAY, 23 July 1995

08:00-09:00	Breakfast
	Session III: "Theory and Engineering Aspects of Optical Design"
	Chairman: Dr. John Taylor
09:00-11:30	Prof. Hans Eichler: "Theory and Engineering Aspects of Optical Design"
11:30-12:00	Discussions
12:00-13:00	Poster Session
13:15-	Lunch
	Chairman: Dr. Robert Walter
16:30-18:30	Prof. Sergie Anikichev: "Laser Resonator Concepts"
18:30-19:00	Discussion Period
19:00-20:00	Poster Session
20:15-	Dinner

MONDAY, 24 July 1995

07:00-08:30	Breakfast
	Chairman: Prof. Hans Eichler
08:30-10:30	Dr. John Taylor: "Beam Transport Optics"
10:30-11:00	Discussion period
11:00-11:30	Break
11:30-13:00	Contributed Papers, # 18, 19, 20 Taner Bulat, Denis Saraev, Wolfgang Hackenberg
13:15-	Lunch
	Chairman: Dr. Ian Spalding
16:30-18:30	Panel Discussion: "Beam Transport Modes - Technology vs Application Driven Considerations"
18:30-20:00	Poster Session
20:15	Dinner

TUESDAY, 25 July 1995

07:00-08:30	Breakfast
	Session IV : Theory and Engineering Aspects of Pumped Lasers
	Chairman: Dr. Bernard Lacour
08:30-10:30	Dr. Ian Spalding: "Electric Discharge Pumping"
10:30-11:00	Discussion Period
11:00-11:30	Break
11:30-13:00	Poster Session
13:15-	Lunch
	Chairman: Dr. David Roessler
16:30-18:30	Prof. Bernard Forestier: "Lase Medium Quality Control"
18:30-19:00	Discussion Period
19:00-20:00	Poster Session
20:15-	Dinner

WEDNESDAY, 26 July 1995

07:00-08:30	Breakfast
	Chairman: Dr. Kirril Prokhorov
08:30-10:30	Dr. David Roessler: "Utilization of High Power Lasers in Metal Working
10:30-11:00	Break
11:00-13:00	Contributed Papers, # 25, 26 Alexander Kubishkin, Yuri Zavalov
12:30-13:00	Discussions
13:15	Lunch
16:30-18:30	Panel Discussion: "The Outlook for High Power Lasers in Industry - Questions of Cost, Reliability, Developed Applications"
18:15-20:00	Poster Session
20:15-	Dinner at the Hunting Cottage

THURSDAY, 27 July 1995

07:00-08:30	Breakfas
	Chairman: Dr. David Roessler
08:30-10:30	Dr. Paul Lovoi: "Utilization of Lasers for Environmental Control"
10:30-11:00	Discussion Period
11:00-11:30	Break
11:30-13:00	Contributed Papers, # 28, 29 Dmitry Gureyev, and Last Minute Submissions
13:15-	Lunch

Session IV : Summary Discussions

16:30-19:00	Dr. Rober Walter: "Outlook for the Future for High Power Lasers" - Introduction to an extended discussion led by Dr. Walter
20:00	Fairwell Dinner

FRIDAY, 28 July 1995

07:00-08:30	Breakfast
	Chairman: Prof. Miroslav Jelinek
09:00- 11:30:	LECTURERS PANEL: Students submit general summarizing questions

SATURDAY, 29 July 1995

Departures

List of Oral Presentations

LIST OF AUTHORS AND PAPERS

NAME		Presentation#	CAPTION
Manenkov	Alexander	1	"History, Current Status, and Outlook for the Future - A Review
Moshkov	Vladislav	2	"Active media disturbances in high power gas lasers"
Witteman	W.	3	"Characteristics of Co and CO2 Lasers"
Lavrov	Alexander	5	Two dimentional model of subsonic CO_2 electric laser
Novgorodov	Maxim	6	Compact slotted RF excited CO_2 lasers of mid power range
Truesdell	Keith	7	"Fundamentals and Current Status of Iodine Lasers"
Hogan	Geoffrey	8	"Fundamentals and Current Status of Metal Vapor Lasers"
Tarasenko	Viktor	9	High power coherent and incoherent uv and vuv sources
Ivanov	Borislav	10	LCVD with Cu vapor and Cu-Bromide vapor lasers
Lacour	Bernard	11	"Fundamentals and Current Status of Excimer Lasers"
Nelson	Thomas	12	Design and analysis of a deep UV laser based on Ce^{3+}: $LiSrAlF_6$
Hening	Alexandru	13	X ray sources from plasma produced by excimer laser
Prokhorov	Kirill	14	Power excimer lasers for monitoring drinking water
Eichler	Hans	15	"Nonlinear Optical Phase Conjugations"
Anikichev	Sergei	16	"Laser Resonator Concepts"
Taylor	John	17	"Beam Transport Optics"
Bulat	Taner	18	The applications of NIR Nd-Yag laser to Raman spectroscopy
Saraev	Denis	19	The features of structure of front of perturbation propagation during pulsive local heating
Hackenberg	Wolfgang	20	The MPE/MPIA laser guide star adaptive optics system
Spalding	Ian	21	"Electric Discharge Pumping"
Forestier	Bernard	22	"Laser medium Quality Control"
Roessler	David	23	"Utilization of High Power Laser in Metal Working"
Kubishkin	Alexander	24	Stress investigation by laser induced thermal waves

LIST OF AUTHORS AND PAPERS

NAME		Poster Presentation#	CAPTION
Zavalov	Yuri	25	Industrial fast axial flow carbon lasers in Russia
Lovoi	Paul	26	"Utilization of Lasers for Environmental Control"

Abstracts of Oral Presentations

CONSIDERATIONS FOR HIGH POWER LASERS APPLIED TO CO_2

W.J. Witteman, University of Twente, Department of Physics,
P.O.Box 217, 7500AE Enschede, The Netherlands

The present paper deals with fundamental aspects of high power lasers. It starts with the amplification of radiation in a homogeneous gain regime. The derivations of stimulated emission cross section, small signal gain, saturation intensity and maximum power extraction from an oscillator or amplifier for a medium with degenerated laser levels are given. For constructing high power laser systems based on active media that have next to inversion production also volumetric radiation losses, for example, by absorbing species, diffraction or light scattering by inhomogeneities the optimization of output power is described in an analytical formula. The applied results are presented in a diagram.

Next, an analysis is given of pulse amplification through an active medium. The conditions are given for total conversion of the inversion energy into stimulated emission during the short period of the pulse. It will be shown how the gain depends on the time behaviour of the input energy and how the total gain is related to the small signal gain and the ratio of total input energy and the saturation energy.

The results will be applied to CO_2 laser systems for generating terawatt pulses. These systems have the potential of generating picosecond pulses since the gain spectrum, although periodically modulated by the rotational structure, has a band width of 10^{12} Hz. Increased pressure and an isotopic gas mixture smooths this discrete gain spectrum. The amplified result depends strongly on the pulse length relative to the dephasing time by collisions, the time that corresponds to the frequency interval between adjacent rotational-vibrational lines and the rotational relaxation time. Detailed results will be discussed. Slicing of picosecond input pulses from nanosecond multiline pulses obtained with mode-locked systems are also discussed.

With respect to recent advances in continuous high power systems we will discuss the radio frequency (RF) technology for waveguide and slab configurations.

Table top devices may now deliver in the range of kW output power with diffusion cooling. This technology with dense discharge power is in principle accompanied by relatively high molecular dissociation. It will be shown how this problem can be circumvented by heating one of the gold plated electrodes. The discharge behaviour will be treated. The dependence on gas pressure, gas composition and frequency of excitation will also be discussed.

two-dimensional hydrodynamics equations

Alexander V.Lavrov, Galina N. Volchkova, Tatiana A. Bungova,
Russian Scientific Centre "Applied Chemistry", 197198,
St. Petersburg, Dobrolubov Ave.14, RUSSIA

In the most part of the papers which deal with a numerical modelling of subsonic gas flow CO_2 lasers with axial discharge the laser output power is calculated on the base of one-dimensional hydrodynamics equations. It is known that very often such approximation makes possible the calculation of output energy with the wanted accuracy. However it is obvious that it is very difficult to calculate a space distribution of T_2,T_3,T_4,gain and boundary heat exchange on the base of one-dimensional approximation. Besides it is apparent that the validity of one-dimensional approximation decreases as the flow rate is reduced and the discharge power loading is increased.

In our paper we suggest a model of subsonic CO_2 laser with axial discharge on the base of boundary layer equations. Two-dimensional parabolic hydrodynamics equations of mass, momentum, energy and vibrational energy are taken into account. The T_2,T_3,N_2,CO,O_2 vibrational temperatures are evaluated. The laser output power is calculated on the base of "average gain equals the average losses" approximation. The influence of the flow rate, tube radius, tube length, discharge power loading on the laser output power is investigated. It is shown that results of the one-dimensional computations differ by 20-30% from the results of two-dimensional computations if the flow rate is about 20 m/s.

Compact slotted RF-excited CO_2 lasers of middle power range

A.A.Kuznetsov*, V.V.Kjun**, V.G.Leont'ev**, M.Z.Novgorodov*, V.N.Ochkin*, E.F.Shishkanov**

* P.N.Lebedev Physical Institute,Academy of Sciences,Russia

** Scientific-Production Corporation "Plasma"

The small size and mass of lasers are the attractive and useful qualities in point of view many practical applications. As the gas lasers, particulary CO_2 lasers the ways in this direction already are assigned. Namelly, the planar geometry of the active medium in conjunction with radio-frequency excitation gave appreciated results. Slab-type CO_2 lasers with output power 10^2-10^3 W are created [1-2].

In this report two models of slab-type CO_2 lasers of the middle power range (30 and 50W) are described. An essential momment is a fact that this models are made on the available industrial technologies base and can be recommended for manufacturing.

The abovementioned laser models are founded on metal-ceramics design (covar, alumooxide ceramics). All metal-ceramic contacts were welded or soldered. For the high reliability provission a such processes as the firing of the internal fittings, degasation and pre-burning were applied. Laser heads contains the gas composition stabilizators in order to sustain constant CO_2 molecules concentration for a long time. The life time test shown that after 1000 hours of continious work the output power have been lowered at 15% for the 30W model.

For pumping the power summation method from two compact semiconuctor RF-generators in phase connected to start and end of discharge line was applied. For forming of symmetric laser beam profile the telescopic unstable resonators were emploied. The beam divergence is near diffraction limited and equals 6 mrad.

Such parameters as laser output power per laser head length and mass are equals 0,71W/cm and 6,7W/kg for 30W model, and 1,04 W/cm, 10,0W/kg for 50W model. This parameters are twice and more higher than one's for many commercial models of similar energy range.

References

1.A.D.Colley,H.J.Baker,D.R.Hall,Appl.Phys.Lett.,61,p.136(1992)

2.R.Nowack,et al. Laser und Optoelectronik,23(3),p.68(1991)

PULSED SOURCES OF HIGH-POWER COHERENT AND SPONTANEOUS RADIATION BASED ON DENSE GASES

V.F. Tarasenko, B.M. Koval'chuk, M.I. Lomaev, V.S. Skakun, E.A. Sosnin, V.F. Fedenev
High Current Electronics Institute of Siberian Division of Russian Academy of Sciences, Tomsk

ABSTRACT

Results of experimental study of high-power wide-aperture sources of coherent and spontaneous radiation are presented. Laser radiation was tested with the help of set-ups of 30 and 600 l volume pumped by an electron beam. Spontaneous radiation was investigated in the spectrum range of 120-350 nm on installations with radiation surface area of 800 cm2 excited by longitudinal, barrier and transversal discharges.

B. Ivanov, C. Popov, V. Shanov, D. Filipov
Higher Institute of Chemical Technology, Dept. of Semiconductors,
8 Kliment Ohridski St., 1756 Sofia, Bulgaria

In the literature there is a lack of information concerning the use of lasers and in the particular a Copper Vapor (CVL) and Copper Bromide Vapor Las (CBVL) in the wavelength range 510 - 578 nm for LCVD of any materials.

1. LCVD of Al from trimethylaluminium (TMA) and trimethylamine alane (TMAA).

The deposition of aluminium stripes in closed reaction cell was carried pyrolytic LCVD process using a focused beam of copper vapor and copper bromide vapour laser up to 130 mm on the surface of an Si (111) monocrystalline wafer. T scanning speed was varied from 10 to 400 mm/s, the laser power was between 0,8 a partial pressure of the precursors from 0.5 to 10 mbar and the background temper the substrate from 300 to 573 K. The morphology of the deposited aluminium shows definite grains which are typical for photolytic deposition of metals. The grain

strongly on process parameters. This was the first time, we believe, that the la was observed using pyrolisis of metal alkyls with visible laser light. This type morphology most probably originates from the pulsed time structure of the light This may cause in an increase in supersaturation and a high nucleation rate, wh the granular structure. We present growth rate behaviour of the stripes and show differences between LCVD with CVL and standard CVD processes. We apply for the f time in kinetic investigations of laser induced direct writing, inductively coup atomic emission spectroscopy (ICP-AES) for quantity of the deposited Al. If we a that surface kinetics is rate limiting for LCVD of Al and by applying of Freundl isotherm we obtain power like dependence between growth rate and partial press TMA which was confirm by the experimental data. If we increase the laser power increasing of the order of chemical reaction of deposition. We believe that the this behaviour is changing of the mechanism of the chemical reaction. Relatively carbon contamination in LCVD written Al stripes using TMA was probably due to th unconventional way of precursor decomposition caused by pulsed laser irradiati secondary reaction of the products that was confirmed by in situ mass spectromet of gaseous phase during the deposition process.

LCVD of Al from TMAA offers some advantages over the common alkyl Al sources being less air sensitive, having simple decomposition pathway, and decomposing a temperature below 120oK. The morphology of the layers and dependence of geometri characteristic versus process parameters are almost the same like in the case of the exception of with behaviour. The carbon contamination in the layer is consid reduced due to the absence of direct Al-C bond. The values of resistivity were c 1.5-3.5 times that of bulk Al. In conclusion should be stressed that the avera density for the deposition of Al from TMAA with copper vapor laser is substantia (at about 100 times) compared to that obtained with Ar+ laser. We consider thi significant advantage of the pulsed visible laser.

2. LCVD of Si from silane.

In order to model LCVD with CVL and CBVL we choose relatively simple and studied chemical system - CVD of Si from silane. We developed new model for temperature distribution at Si surface induced by CuBr laser taking in to accoun of laser pulse which lead to quite deferent resultants in comparison with the li results assuming rectangular shape pulse structure. Analytical model describing kinetic systems are proposed. The analytical approach is based on the Kirhoff tr and Green function analysis of nonlinear heat diffusion problem. The known kinet models for dissociation of SiH_4 are applied. The processes are modelled for dif parameters of the laser irradiation - spot size, laser power, shape and length o The experimental results include maskless deposition of silicon from silane on monocristaline wafer using CBVL. The influence of process parameters on the g and morphology of the obtained stripes are presented and some conclusion for process mechanism are made. The predicted widths according to the model are ver to the experimentally obtained values in contras of predicted heights.

FUNDAMENTAL AND CURRENT STATUS OF EXCIMER LASERS

Bernard LACOUR

LASERDOT, Groupe Aerospatiale
Route de Nozay, 91460 Marcoussis, FRANCE

Abstract

Excimer lasers are to day more than twenty years old. Hence it can be said that they now come of age and to maturity. Numerous experimental devices have been tried, numerous assertions, sometimes contradictory or excessive have been heard. Theoretical models have become more and more complex and complete though they are not ever able to predict if a discharge will be homogeneous or not !

The aim of this lecture will not be to speak on every thing more or less related to excimer lasers, but to select the main points and to try to give a physical understanding of what happens un such a laser.

During a first part we shall recall basic principles of excimers : these wonderful molecules which can only live if excited and even then only for a short time ! Several means can be used to produce them but the most widely used is the pulsed electrical discharge. The study of the conditions for obtaining a homogeneous discharge in a high pressure gas mixture will naturally constitute an important chapter of this first part.

Finally, we shall discuss on the temporal and shot to shot stability of the discharge which allows to obtain long laser pulses and to operate the laser at high repetition rate.

The second part of this lecture will be more practical and we shall describe several typical devices. Excimer lasers' history has followed successive steps : after the first discovery research on laboratory devices, the work done at the beginning of 80 years, mainly in USA led to new, interesting and sometimes spectacular results in term of energy per shot, efficiency and repetition rate.

More recently Europe and Japan decided to promote research programs oriented towards the carrying out of high average power, industrial excimer lasers. Their objectives have now been reached and the description of the lasers born of the AMMTRA and EUREKA programs will close this lecture.

Design and Analysis of a Deep UV Laser based on Ce^{3+}: $LiSrAlF_6$

T.R.Nelson, F.G. Omenetto, W. Andreas Schroeder, J.W. Longworth, and C.K. Rhodes

Ce^{3+}:$LiSrAlF_6$ (Ce:LiSAF) has been demonstrated to lase between 280 and 320 nm by several groups. This offers an attractive laser source for biophysics, physical chemistry, and ultra-intense physics.

Given the successful operation of Kerr Lens Modelocked (KLM) Cr^{3+}: LiSAF oscillators in the red and near infrared, we have undertaken the analysis and design of a KLM oscillator and amplifier system based on Ce:LiSAF. The absorption band edge of the colquiriite host can be estimated to be in the region of 130 - 140nm, from the absorption properties of its constituents. This suggests minimal two-photon absorption of the UV radiation by the host. Furthermore, this indicates that the second order index of refraction (n_2) should be positive and capable of supporting KLM operation. An optics matrix analysis is used for the optimization of the oscillator design. Since Ce:LiSAF has an absorption band centered near 260 nm, a limited number of pump sources are available. A comparison of those sources is also presented.

In addition, since the bandwidth is capable of supporting sub-100 femtosecond pulses, the material is a promising gain medium for amplification to high peak powers. An outline of a power amplifier will be discussed to describe the development of a Terawatt class 290 nm, 50fs laser system.

POWER EXCIMER LASER FOR DRINKING WATER MONITORING

S.S.Alimpiev, S.M.Nikiforov, Ya.O.Simanovskii, K.A.Prokhorov
General Physics Institute, Russian Academy of Sciences,
38 Vavilova str., Moscow 117942, Russia

Dramatic degradation of the quality of drinking water is one of the global ecology problem. Widely used biological methods of drinking water final purification may deteriorate situation due to producing very dangerous biological toxins. Our research was directed to develop the laser spectroscopy method of efficient detecting biogeneous organic contamination of drinking water. Short wavelength and high peak power excimer lasers are widely used for studying bioorganic compounds by fluorescence spectroscopy. We have tested the all types of excimer systems for the excitation the laser induced fluorescence (LIF) of drinking water samples. Experiments have shown that only KrF system lasing at 248 nm gives the significant advantage in LIF detecting a lot of bioorganic admixtures, including biotoxic components.

This shortest excitation wavelength gives resonance fluorescence at 300-310 nm, which is very interesting for us because this band is typical for diabolic macro molecules with aromatic group, whereas more traditional UV sources like XeCl (308 nm) and nitrogen (337 nm) lasers could excite fluorescence only in the visible region. Another advantage of 248 nm excitation is that in the fluorescence spectra of water samples one can observe narrow peak at 271 nm which is the Raman line of water molecule vibration. This Raman line gives an excellent reference for this kind of measurements. All LIF spectra obtained in this work were normalized to the Raman line of water itself.

LIF spectra of variety of samples were recorded, including tap water of huge cities, spring and canned drinking water, deionized water. General features could be summarize in the following manner:

a. Two bands clearly appears in the spectra of drinking water at 300-600 nm.

b. The band at 305-310 nm is associated with macro molecules having aromatic group like tyrosine containing polypeptides. This band is also detected in the samples of industrial waste water.

c. The band around 430-450 nm is always present in the spectra and corresponds to organic contamination with molecular weight in the range of 1-10 kDalton and having biogeneous nature.

d. The LIF intensities of purified, "clear" water samples are linear with concentration of impurities and are sufficient for detection in laboratory condition under 3-5 mJ per pulse laser excitation.

e. In the soil, waste water with numerous impurities LIF spectra at 300-600 nm region have ambiguous meaning.

Our results demonstrate that with relatively powerful KrF laser the method could be very promising for final remote control of drinking water products.

Laser Resonator Concepts

S. Anikitchev

ABSTRACT

Our principal concern will be with the area of powerful CO_2 lasers for industrial applications (lasers with open and wave-guide cavities), powerful solid-state, eximer, metal-vapour lasers and chemical lasers.

All laser resonators may be classified under three chief groups:

- open resonators for lasers with usual form of its cross section (circular or right-angled);

- open resonators for lasers with annular form of active medium and

- wave-guide resonators.

1. At the beginning the open resonators with usual cross section of the active medium are discussed:

- general mathematical description, some important properties of resonator modes, numerical techniques, semianalytical techniques;
- stable resonators:

  eigen modes and analytical criterion of single-mode lasing, applications of stable resonators;
- unstable resonators for powerful lasers in general and

  - multipass unstable resonator of considerably reduced sensitivity to misalignments and of lower parasitic losses, its possible applications,

  - unstable resonator with semi-transparent output mirror that provides an increase in axial luminous intensity;
- comparatively new type of resonators with spatial filtration - formally stable semiconfocal resonator with diffraction output of radiation, its applications.

2. At the second section resonators for lasers with annular form of active medium are discussed.

- An astigmatic telescope transforming the annular into rectangular beam cross section with a simultaneous transformation of the radial or tangential polarisation into linear one;
- new resonator with high effective length based on the above mentioned astigmatic telescope.

3. At the third section some new resonator arrangements for wave-guide CO_2 industrial lasers with annular form of active medium are discussed.

- Introduction, resonators for wave-guide lasers of slab geometry;
- optical arrangement decreasing the Fresnel number of coaxial wave-guide resonator;
- Talbot-resonator for coaxial wave-guide lasers;
- possible implementation of astigmatic telescope for coaxial wave-guide lasers.

Beam Transport Optics

John R. Taylor

Lawrence Livermore National Laboratory
Livermore, California 94550

Abstract

Beam transport optics receive output energy from the laser cavity and deliver it to the work site. Depending on the application, this may require a few simple elements or large complex systems. Transport of high-power laser beams share common objectives, although the techniques used may vary, depending on the type of laser source and environmental conditions. Collection of the laser energy depends on the spatial and temporal energy distribution as well as the wavelength and polarization of the laser cavity and output coupler. Transport optics can perform a variety of functions, including beam formatting, frequency doubling, and distribution to one or more work sites while maintaining or even improving the beam quality. The beam may be delivered to work sites as focused spots or images, projected to distant targets, or propagated through various media for sensing or photochemical processing.

The variety of applications leads to a wide range of approaches to the design of the beam transport system. Design may involve optical modeling of the system, including diffraction effects and thermal management. Beams often are characterized as Gaussian for convenience in modeling. When deviations from this ideal profile need to be considered, it is necessary to characterize the laser beam in detail. Other beam profiles are sometimes advantageous. Design of the transport system requires understanding of the interaction of the laser energy with optical materials and components. Practical considerations include mounting the optics without stress and with the stability suitable for the intended application. Requirements for beam direction, stability, size, shape, and quality dictate the design approach for each specific situation. Transport optics may consist of windows, lenses, mirrors, and various components for combining or splitting light on the basis of intensity, wavelength, or polarization. Transport via waveguides or fibers can offer useful system flexibility.

Attention also must be given to reliability, environmental, and commercial requirements. Damage to optics in high-power laser systems is a common concern. Environmental problems such as atmospheric turbulence, contamination by dust or vapor from the work site or other sources, or absorption of water vapor can directly degrade beam quality. Other potentially significant optical performance effects may result from instability and aging of the optics, temperature, humidity, pressure, transmitted vibration, and contamination from the work site or other sources. In commercial applications, designs must meet the customer's specifications and needs at a reasonable cost. Design parameters will differ greatly when applying high-power lasers to diverse applications such as large-area cutting, medical surgery, microlithography, or inertial confinement fusion.

Design of optical components includes material selection, fabrication tolerances, and coating requirements. Component specifications are sometimes best handled by describing the performance requirements for the optics. Optics for high-power applications tend to have unique characteristics. Ensuring that optics perform as specified is an important part of optimizing total laser system performance. Testing optics performance and qualifying vendors to meet system requirements and specifications are key components of this process.

Optimizing beam transport systems may include cooling active components or subsystems that provide automated pointing, centering, and wavefront control. Visible beams can be added to provide a safe and simple method of aligning the high-power laser beam on the work site or to maintain alignment and quality over long distances.

Several beam transport optics systems (including both simple and large complex systems using a variety of laser sources) and examples of component specifications and methods of testing important performance requirements illustrate these fundamental and practical issues.

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THE APPLICATIONS OF A NEAR-IR LASER TO RAMAN SPECTROSCOPY: FT-RAMAN SPECTROSCOPIC STUDIES OF ADSORBED SPECIES BY CLAYS.

Taner Bulat*, Sevim Akyüz*, Tanıl Akyüz** and J.Eric Davies+

* Physics Department, Istanbul University, Vezneciler 34459, Istanbul, Türkiye

** Çekmece Nuclear Research and Training Center, P.K. 1 Havaalanı, İstanbul, Türkiye

+ Environmental Science Division, Lancaster University, LA1 4YQ, U.K.

The use of IR spectroscopy for the analysis of clays is well known, and has been established over a long period of time. However, Raman spectroscopy has found little use to date for the study of clays, due to the weakness of the Raman scattering signal, the occurrence of thermal or photodegradation of the sample, and the occurence of fluorescence which swamps the Raman signal, although it has several advantages. The advantages of Raman lie in the fact that it detects primarily the symmetric vibrations and results in simpler spectra without overtone and combination bands.

Recently, FT-Raman spectrometers, operating by near-IR laser excitation, has been introduced to overcome the problems: Fluorescence is dramatically reduced, signal-to-noise can be improved by the co-adding scans and the use of the longer wavelength of the exciting light reduces the problems of sample degredation under the laser.

In this study both FT-Raman and FT-IR spectra of adsorption of bipyridyls (4'-4'- and 2-2' bipyridyl) by sepiolite and smectite group clay minerals from Anatolia has been investigated. Raman spectroscopic investigation has been found to be very useful in shedding light on the host-guest interaction, since it enables one to analyze clearly the 1100-950 and 600-400 cm^{-1} regions of the spectra of adsorbed molecules, regions which are obscured in the IR spectrum by the host vibrational modes of aluminosilicate. In the case of adsorption of 4-4' bipyridyl the vibrational analysis indicate that the molecules adsorbed on sepiolite are centro-symmetric and act as a bidentate ligand whereas the molecules adsorbed on smectites coordinate to exchangeable cations as a monodentate ligand. On the other hand the vibrational spectroscopic study of 2-2'-bipyridyl treated clays studied indicated that two different types of surface species are generated: chemisorbed neutral molecules and chemisorbed monoanions.

The Features of Structure of Front of Perturbation Propagation during Pulsive Local Heating

S.G. Psakhie, D.Yu. Saraev, S.Yu. Korostelev

Institute of Strength Physics and Materials Science Russian Academy of Sciences, Russian Material Science Center, 2/1 av.Akademicheskii, Tomsk, 634055, Russia

High-power lasers pulsive action techniques allowes to modify properties and structure of materials substantially. It leads to wide usage of this technique in practice. Experimental research on the response mechanisms of materials on the atomic level is an exteremly complicated problem because of the short characteristic time and length scales. This has predefined the wide use of modelling methods in researching of such phenomena. It should be pointed out that usually the primary attention is devoted to the modelling of shock-wave loading. Local heating causes the excitation and propagation of a nonlinear wave in the material. The general features of propagation of these perturbations can be studied using 1-**D** models by analogy with shock waves. This approach can be used for direct studies of nonlinear properties of the system since there are no effects related to rearrangement of the atomic structure.

In this paper the above pointed problem was solved by modeling a one-dimensional aluminum lattice with an interaction potencial calculated with the pseudopotencial method. At the initial time the local region with the high temperature is specified. The intensive local heating leads to the rapid thermal expancion of this region and therefore initiates a perturbation wave in the medium.

Obtained results allows us to state that the solitary waves produced during pulsive local heating are solitons, behavior of which is similar quite to behavior of the solitons formed during propagation of shock waves. Thus the propagation of a shock front in nonlinear medium and the propagation of the perturbation front formed by a local pulsive heating have certain features in common. In both cases the leading edge of the front is a set of solitons. This means that a lot of experimental and theoretical data on the propagation of shock fronts may be used to analyze the propagation of a perturbation front produced by local pulsive heating. However, it should not be forgotten that the behavior of the front following the first perturbations will be substantially different in these two cases of loading. Thus in the shock loading a compression wave follows the solitary waves, but in the case of local pulsive heating a thermal wave propagates instead of the compression wave. It means to be expected that an effect of perturbation fronts on the material in the case of heating will be more complicated than that one under shock loading.

Institut de Recherche sur les Phénomènes Hors Equilibre

Unité Mixte, du C.N.R.S. et des Universités d'Aix-Marseille, N° 138

NATO
Advanced Study Institute on High Power Lasers Science and Engiuneering.
Karlovy Vary july 1995.

Laser medium quality control, Bernard Forestier.

The lecture will be focused on the influence of laser medium quality on the average power and the laser beam features in the case of excimer lasers. The wavelenght (UV domain) and the energy density level of pulsed excitations justifie this restriction of the topic. The lecture will approach different concepts in the chapters briefly described hereafter.

- A rapid survey of excimer laser programs will be given. The main constraint related to high average power excimer devices will be underlined. Very simple rules deduced from fluid mechanic or optic analysis will be given in order to optimise laser power energy and laser beam quality.

- Flow loop descriptions.

- Flow diagnostics.

- Pressures waves induced by the active medium excitation.

- Dampers and diffractive devices for acoustics waves.

- Experimental studies of acoustics waves behaviour on "LUX" testbed at Marseille IMF / IRPHE.

- Numerical studies.

- Conclusions

Laboratoire Lasers, Plasmas et Procédés Photoniques (LP3) - Pôle scientifique et technologique de Luminy, 163 avenue de Luminy, 13288 Marseille cedex 9. Tel. (33).91.26.92.82 Fax. (33).91.26.92.89, E-mail : newlaser@mfmcalas.univ-mrs.fr

UTILIZATION OF HIGH POWER LASERS IN MATERIALS PROCESSING - AN AUTOMOTIVE PERSPECTIVE

David M. Roessler
Physics Department
GM Research and Development Center
Warren, MI 48090-9055

NATO Advanced Study Institute on High Power Lasers

ABSTRACT

Lasers were being used for machining purposes in the automobile industry as early as 1969 and, since then, the applications have expanded in both diversity and in power range. This review traces the history and growth of this experience on a global basis.

We first consider some very elementary aspects of laser-material interactions, leading to a discussion of the power and irradiation duration regimes appropriate to processes such as welding, cutting, drilling and so on. A brief description is then given of basic aspects of beam delivery - the process by which the laser beam is conveyed from the laser head to the workpiece. This is nontrivial in terms of the economic aspects of industrial laser machining and may account for half of the total capital investment. We conclude this tutorial introduction by noting some of the basic optical parameters of laser beams and associated optics and their role in the material interaction process.

One of the most intriguing aspects of industrial laser machining is the degree to which lasers are often used in a very unsophisticated fashion - partly because our detailed knowledge of the material interaction phenomena is inadequate but partly because much can be accomplished even by a "brute force" approach. The main section of this review focuses on the primary applications of lasers in the automobile industry and provides considerable evidence that, despite the progress made thus far, there are many opportunities for improvements in future. Some of the topics covered include currently "hot" applications such as the welding of tailored blanks and the cutting of option holes.

The concluding section looks to the future in terms of developments and needs in both laser technology and processing. The advent of commercially available high-powered solid-state lasers amenable to fiber optic beam delivery is already significantly impacting the industry. The prospects of diode-pumped systems expands their potential even further - although economic considerations may defer automotive plant floor implementation in the near term. We will also discuss the outlook for alternatives to the most common lasers (the CO_2 gas laser and Nd:YAG) and the automotive future for the excimer, CO, and free-electron lasers, for example. The laser is expected to play a increasing role in the future with the anticipated changes in the design, materials, and needs in next generation automobiles.

Investigation of inner stresses in metals by laser thermal-wave technique

A.P.Kubyshkin

Russian Academy of Sciences
Scientific Research Center for Technological Lasers
Shatura, Moscow Region, 140700 Russia
Tel/Fax +07-(095)-135-54-30

It is well known that the investigation of inner stresses in structural elements involves considerable experimental difficulties. At the same time, this problem is topical in machine-building, particularly by the analysis of the constructions mechanical properties, by estimation of their reliability and durability. The paper presents the results of investigation on a possibility of revealing inner stresses in metallic parts by laser excitation and analysis of thermal waves.

Stressed states in model samples were generated by applying outer mechanical load and were studied with the use of laser thermal-wave microscope employing the principle of laser photothermal radiometry. For thermal waves excitation, a Nd:YAG laser beam was used, that was modulated in accordance with the harmonic law and focused onto the sample surface. The IR photodetector was employed to study the peculiarities of thermal diffusion in the vicinity of laser probing region by recording IR radiation from the surface. Full noncontactness and nondestruction on testing are the advantages of this technique.

It has been revealed that on applying the mechanical load causing inner stresses, thermal diffusion in the stressed region takes on anisotropic nature. The induced anisotropy values depend on the amount and direction of loading forces. A theoretical estimation of the effect under observation was made. Thus, a possibility of studying stressed states is shown with locality in the order of 0,1...1 mm that is governed by the thermal-wave microscope resolution.

The results of this technique application to the study of the regions of fatigue stresses locality in turbine blades of the Russian airplane IL-76 are also presented.

The discussions are held on the possibility of this technique application to evaluation of stresses in metals on laser processing, i. e. in surface layers on laser heat hardening and in the heat-affected area on laser welding.

Industrial Fast Axial Flow Lasers in Russia.

Zavalov Yu.N.

Russian Academy of Sciences
Scientific Research Center for Technological Lasers
Shatura, Moscow Region, 140700 Russia
Tel/Fax +07-(095)-135-54-30

For automatic technology of metal cutting the laser complex tool on basis single mode fast axial flow CO2 laser with output power range of 1...3 kWt is quite enough.

Under unfortunately forces of various contingencies in Russia the elaboration of the single mode fast axial flow (FAF) CO2 laser was begun only in the late 80s. In particular the Scientific Research Center for Technological Lasers began R&D works in this line of inquiry with study as well DC longitudinal discharge laser as RF (13.56 Mhz) transverse discharge laser. After some experimental efforts, when stable discharge was realized with specific volume power over 10 Wt/cm3 both to one above and to other,

the DC discharge laser was elect for practice realization. In this case the industrial tool contrasts with simple service, high level reliability and rich laser mode multitude.

Nowadays representative laser TLA-600, first of assumed series of lasers with correspond output power 600, 1200, 1800 Wt, have been designed. The laser works as well cw mode as high repetition pulse (HRP) mode under microprocessor controller (MPC).The HV insulate fiberoptic wire connects MPC with discharge current regulator in series channel circuit. Maximum single mode output power is 650 Wt, but for predominantly TEM*01 beam mode maximum output power is 750 Wt with 18% efficiency (for 600 Wt output power efficiency is 22%) with 60 l*atm/h gas mixture consumption . (Industrial purity gases were used).

Enhanced pulse mode was realized: in the range of frequencies 800...1200 Hz peak power excess over average level is to 8, but for 250 mcsec load power pulse duration the pulse energy exceeds 300 mJ in frequency range up to 1500 Hz.

For good understanding of the FAF laser optic resonator particular calculation some experimental and theoretical works were carried out to investigate the effect of gas turbulence flow uniformity on the beam quality and output power level. Beam transverse distribution for single gauss output radiation was measured by LBA-2/A, that was set on distance more than Relay length. It was found that beam divergence was near diffraction limit for our laser aperture.

We had studied different HRP mode technique. In particular we used passive Q-switched technique for realization HRP mode in 10 kHz frequency range. In combination of this technique with current modulation we realized the HRP mode with peak power excess over average more than 20-50 and pulse repetition frequency in order of some kHz magnitude. Devoting enhanced attention to laser HRP mode we had took into account non-traditional sphere of application, for example, in selective laser molecular technology, or as lidar source or as for some material thermal processing.

Abstracts of Poster Presentations

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EXPERIMENTAL STUDY OF OPTICAL METAL AND ALLOY CHARACTERISTICS IN VACUUM FOR OPTICAL WAVELENGTH RANGE UNDER POWERFUL HEAT AND LASER AND IMPULSE EFFECTS

Kozlova A.S.

MOSCOW AVIATION INSTITUTE

Melting and evaporation stages of metals are in the basis of numerous technological processes developed in the field of metal treatment [1]. Lasers enable to heat the surface of metals by powerful short-term radiation that considerablychanges the properties of their surface. The necessity to study the optical characteristics of metals and alloys subjected to such treatment becomes of vital importance.

This paper considers the method and represents the measurement results of solid and liquid metal target reflection ability in vacuum under neodim laser impulse effect acting in the mode of free generation. The techniques presented are based on the comparative method of reflection factor RF measurement and a widely-spread method of measuring a reflection factor of diffusionally scattering surface described by Taylor . The measurements were taken during a hundred ms after the laser impulse effect on the target using a system of laser synchronisation with spectral RF measurement [2]. The RF temperature dependece for freemelting metals (tin, indium) within the interval of 20'C to 350'C has been obtained for optical ranges of scanning emission in vacuum no more 10(-4) Torr under the neodim laser effect (facility GOS-1001), the beam energy up to 1 KG and maximum emission power density at the target being 10(5) W/sq.cm.

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RECONSTRUCTION OF A LIGHT BEAM WAVE FRONT BY SYNTHESIS OF A SHEAR INTERFEROGRAM.

V.N.Shekhtman, A.Yu.Rodionov, A.G.Pel'menev

At solving problems of radiation wave front reconstruction, shear interferometers have obvious advantages relative to interferometers with reference beam. They are connected in particular with the fact that in the shear interferometers any reference beams are not required. Although shear interferometers are convenient in service and have a low cost, their application is typically limited by the complexity of interpretation of shear interferograms and by the incomplete information contained in them.

The various reasons for loss of information on a beam wave front profile obtained with the use of shear interferometrs are widely described.

The first kind of loss of information is the selective sensitivity of shear interferometers to different spatial frequencies of wave front inhomogeneities,including the complete absence of sensitivity at some frequencies.

The loss of information of the second kind is due to incomplete filling the aperture of tested light beam with interferometric fringes.In practice it results in the discrete wave-front representation with a step equal to the value of the shear.

The third factor lowering the information content of conventional shear interferograms is the absence of data on first-order aberrations.

In this report a practical method is proposed for reconstruction of a light beam wave front without the use of a reference wave. The proposed principle is due to synthesizing an interferogram containing the information on the wave front identical to that given by a reference beam interferogram. The method is illustrated using reverse and lateral shear interferometers as the examples.The report specifies the requirements imposed on the interferometer setting-up which allow to avoid all information losses peculiar to conventional lateral shear interferometers. The processing of such synthesized interferograms is suggested based on the Fourier transform. Results on wave-front measurements using the proposed technique and a Michelson interferometer are compared.

DYNAMICS OF LASERS WITH PASSIVE AND ACTIVE MODULATION OF LOSSES

L.A.Kotomtseva, A.M.Samson, S.I.Turovets

B.I.Stepanov Institute of Physics of the Academy of Sciences of Belarus

Results of the theoretical consideration of regular and chaotic dynamics and targetting to unstable orbits for some models of lasers with passive and active modulation of losses are proposed.

For a laser with a saturable absorber (LSA) on the basis of semiclassical equations [1] conditions and mechanisms for the appearance of regular and chaotic dynamics are considered and various models describing such behaviour are discussed [2-4]. For the LSA system of equations for the interaction of an inversion of populations and polarization of active and passive media in the cavity leads to bifurcational tree, that has been described in [1] for the resonant case when the central frequencies for active medium and absorber coincide with the proper frequency of the cavity. For the detuning of such frequencies dynamical behaviour with rotating phase has been got [2] and steady states and their stability are discussed.

For the parameters of CO2 LSA model with two longitudinal modes over the threshold has been considered and some succesions of bifuracions have been got, which are in good agreement with experimental results, as it is seen in [3].

Road leading to changing of number and stability of the steady states in more complicated system of a laser with two saturable absorbers has been proposed in [4] for the most simple model of incoherent interaction with light and is considered in this report.

For a laser with active modulation of losses rich variety of multistable regular and chaotic dynamics has been got [1,5] in good correlation with experiments for CO2 lasers.

Both for active and passive modulation of losses method for targetting to unstable orbits has been considered [6] and it's advantages and conditions for an experimental realization are discussed.

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Nd:YAG SOLID-STATE LASERS FOR MATERIAL PROCESSING AND MEDICAL SURGERY

V. LUPEI, T. DASCALU, S. GEORGESCU, N. PAVEL, and C. LUPU
Institute of Atomic Physics, Bucharest R-76900, Romania

The Nd:YAG laser is now a common tool in scientific research or in applied fields such as materials processing, electronics industry, medicine and so on. The possibility of using the thermal effects of the laser irradiation on surfaces as a temporally and spatially controlled source of heat opened a large variety of technological applications such as surface thermal treatment, welding, drilling, cutting, marking, resistor or capacitor trimmering and so on. In medicine this laser was used for open or endoscopic coagulation, ablation or rezection surgery, lithotripsy, breakdown intraocular surgery, dentistry, etc.

Since 1975 we developed a variety of such lasers based on active media and devices produced in our laboratory. Basically these lasers could be grouped into five categories: (i) CW multimode or monomode YAG:Nd lasers with one-rod and multimode power up to 300 W; research on multiple rod or slab lasers is now in progress. Our activity included research on thermal effects induced by optical pumping in the active media and their compensation, stable or unstable resonators, large volume monomode generation and so on; (ii) CW pumped - repetitively switched lasers. Various active (acoustooptical or mechanical), passive (Li:F2- or transition metal-doped crystals) or combined active-passive methods have been used for switching at repetition rates from hundreds to 20 KHz; (iii) long-pulse (up to 10 ms), high-average (up to 20 J/pulse and 100 Hz repetition rate) YAG:Nd lasers; (iv) giant or high brightness pulse generation with repetition rates up to 100 Hz and peak power to 20 MW; (v) frequency doubled CW or pulsed YAG:Nd lasers; (vi) diode pumped lasers.

These lasers have been used for investigation of various technological processes: welding of thermally - sensitive parts or of unusual materials, drilling of metals or hard materials, controlled cutting of metals and ceramics, silicon wafer marking and so on. A small production of such devices was organized which fulfilled most of the country's need. Dedicated technological equipment with lasers and controlled X-Y positioning of the parts to be processed or controlled scanning of laser beam on surfaces has been designed and build. In the field of medicine our interest was directed toward coagulation, contact surgery and ablation, breakdown ocular-surgery, kidney lithotripsy, etc.

In order to act as an interface between our research and industry or education a center for Advanced Solid State Applications was organized. This center is aimed for demonstration, training or small scale applications

DETERMINATION OF THE TIME DEPENDENT RESISTANCES AND INDUCTANCES OF THE DISCHARGES IN A PULSED GAS LASER THROUGH ITS CURRENT WAVEFORMS

P. Persephonis, V. Giannetas, A. Ioannou, J. Parthenios and C. Georgiades

University of Patras, Department of Physics 26500 Patra GREECE

ABSTRACT

In the present work the time dependent resistances and inductances of the electric discharges in a pulsed gas laser are revealed through the current waveforms of the circuit. This can be achieved combining step by step the experimental current waveforms with the current integrodifferential equations of the system. Thus digitizing the signal, the first derivative is calculated through a computer. For a certain time instant, substituting the value of the current and its first derivative into the integrodifferential equations describing the performance of the circuit loops, we form relationships which connect the values of the resistance and inductance for this particular time instant. Combining relationships originated from very closed adjacent time instants, the values of the resistance and inductance can be found. Scanning the entire time region of the discharge, the time dependence of the resistances and inductances of the discharges are revealed. Their behavior shows for the resistances an abrupt drop while for the inductances a sharp peak, both during the formation phase. After that the above characteristic quantities fluctuate slowly around constant values. The sharp drop of the resistance was expected bearing in mind that the number of the charges increases dramatically through the electron avalanche multiplication during the few first nanoseconds causing the abrupt reduction of the resistances. On the other hand the sharp peak of the inductance was unexpected. A plausible explanation of this phenomenon is that the plasma undergoes a temporary constriction which is due to the predominant attractive magnetic forces during the formation phase of the discharge.

MOLECULAR DYNAMICS IN EXCIMER LASERS

Vitaly V.Datsyuk

Department of Physics
Kiev T.Shevchenko University
Kiev 252017, Ukraine

This paper reviews one-decade, from [1] to [2], development of the analytical model of vibrational relaxation of rare gas halide (RgX) excimers. The main goal of the theory is to explore reasons of reduction and find ways for improvement of the efficiency of the excimer lasers. Studied factors are

- the finite rate of RgX relaxation over large number of vibrational levels in the excited electronic states;
- the internal energy of initially generated excimers;
- saturation of light flux in laser resonator;
- the finite rate of removal of the low laser level.

As to modeling molecular kinetics in the RgX lasers it is particularly emphasized the impossibility to use one universal set of kinetic parameters. Contrary to the common concept, we predict dependence [2] of both the effective radiative lifetime and quenching rate constants on

(i) time type of problem (steady-state or pulse),

(ii) the internal energy of generated excimers, and

(iii) gaseous-mixture composition.

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Reproducible Ultrashort Pulses and Multistable Monochromatic Emission from Solid-State Lasers with Saturable Absorber and Negative Feedback Loop

K.P.Komarov

Institute of Automation and Electrometry of the Russian Academy of Sciences, Novosibirsk, Russia

We present the overview of our investigations on various operation regimes of solid-state lasers with a saturable absorber and a stabilized negative feedback loop. The passive mode-locking of these solid-state lasers is similar in their characteristics to passive mode-locking of dye lasers: after transient evolution the reproducible regime of single stationary pulse is realized, and extremely short duration of pulses is reached. The report contains results of theoretical analysis and experimental research of stabilized passive mode-locking for various solid-state lasers: ruby, Nd:phosphate and Nd:silicate glasses, potassium gadolinium tungstate, Nd:YAG. These results are concerned of stability conditions, transient evolution, laser light dynamics, steady state regime, its spatial and temporal-spectral characteristics, transverse and phase modulation instabilities and methods of their suppression.

It is shown that in the case of the sufficiently slow saturable absorber the multistable monochromatic generation is realized (in a linear resonator such saturable absorber acts as a nonlinear intracavity selective component with the transmission maximum at the emitted mode frequency, and as a result the single mode regime is reached). Required parameters of the laser and the negative feedback loop for origin of this regime have been determined

The regimes under study are of interest in the development of solid-state laser sources of reproducible power ultrashort pulses and high-power monochromatic radiation with a stable frequency. Furthermore, the laser system under investigation provides a way of studying the nonlinear light dynamics under long-time self-influence of radiation in nonlinear media.

PHYSICAL CONCEPTION OF 50 KW AIR-BREATHING LASER

V.G.Vostrikov, A.G.Krasukov, V.G.Naumov, P.A.Svotin, L.V.Shachkin, and
V.M.Shashkov. Troitsk institute for innovation and fusion research
Russia, 142092 Troitsk, Moscow region.

ABSTRACT

Physical restrictions to operating parameters of air-breathing e-beam sustained CO_2 -laser are considered. Self-consistened numerical calculations of discharge and gasdynamic characteristics, vibrational kinetics and lasing are fulfiled. The possibility of active medium pumping is demonstrated experimentally.

In this paper we consider physical restrictions to operating parameters of air-breathing e-beam sustained CO_2 -laser. Electron density in discharge chamber of such a laser is usually controled by three-body attachment of electrons to oxygen molecules q = nua*ne . Here q is e-beam ionization rate q = Ä*jb*p, where Ä = 10^18 cm^-3*s^-1, jb is e-beam current density [mA/cm], p is the gas pressure [atm]. Attachment frequency in air with a small additives CO_2 and H_2O (5% and 1% respectively) is given by expression nua = 2.5*10^7*p^2 [s^-1]. Preliminary experiments at p = 150 - 300 Torr and discharge duration td = 100 - 300 mcs show that discharge is stable up to reduced electric field E/p = 5 kV/cm atm. Specific energy input of 200 - 250 J/g is obtained. In this case discharge input power density is given by w = 1.1*10^2*jb [W/cm^3] and is depended only on e-beam current density and is not depended on gas pressure (at given E/p). The mean discharge power density (wm) is depended only on mean e-beam current density (jb,m). Now jb,m = 40 mcA/cm^2 is technically available and wm ~ 4.5 W/cm^3 can be achieved not depending on pressure. To determine laser generation efficiensy in such a mixture we have fulfiled self-consistened numerical calculations of discharge and gasdynamic characteristics, vibrational kinetics and lasing for specific input power 150 - 250 J/g. This calculations show that at optimal unstable resonator transparency lasing efficiency of 10 - 14 % can be realized. To agree rates of pumping, vibrational and radiational relaxation, discharge duration should satisfy the condition td < 100/p [mcs]. So our consideration shows that to obtain mean laser output power of 50 kW discharge chamber volume of the order of 0.1 m^3 is to be realized. As was shown above the gas pressure is not the parameter of problem and the operating gas pressure should be determined on the base of the other reasons. At first the convenience of gas flow organization and energy consumption for gas blow is to be account. On the other hand pulse duration should be consistent with specific laser technology requirements. To solve the problem of remote laser cutting and thermal surface processing of materials the pulse duration td 150 - 500 mcs is acceptable and the gas pressure may be 150 - 300 Torr. It should be noted that the pulsed e-beam current density must be increased as the square of pressure and for p = 150 - 300 Tor is to be 1 - 5 mA/cm^2 . The gas flow rate should provide full exchange of gas in discharge chamber between pulses including gasdynamic expansion of heated gas. To obtain mean laser power of 50 kW the gas mass flow of 4 - 5 kg/s is nesessary.

we have developed the conception of air-breathing e-beam sustained 50 kW CO_2 -laser. The general features of installation, overall dimensions and technical requirements to main systems are determined.

STUDY OF NEW GAIN MEDIA FOR HIGH POWER VISIBLE AND NEAR IR GAS LASERS

V.V. Naumov, I.A. Izmailov and V.A. Kochelap, Ukrainian Academy of Sciences Kiev 252650 UKRAINE

To look forward to new trends in modern gas lasers and its applications, current theoretical and experimental studies (state-ofart) on search of new active media in visible and near IR spectrum for high power short wavelength gas flow lasers are reviewed.

The general problems (optical, thermal and fluid dynamic) in operation of gas flow lasers on electronic transitions are discussed. The perspective electronically excited diatomic molecules (halogens, halkogens and other possible candidates from the elements of Group VI and VII) as the potential lasants and exoenergic gas-phase reactions of radiative recombination of atoms in supersonic flows (S+S, Br+Br, Cl+Cl and others) as the most perspective way to pump a high energy active media are found.

The key spectral and kinetic characteristics (recombination efficiency, its branching ratio, quantum yields, rates of E-V-T energy relaxation, radiative lifetimes, etc.) important for pumping of the electronically excited B-X band system of S2, Br2, Cl2 and other molecules are analyzed. The initial thermodynamic parameters, gas mixture composition, flow pressure and temperature regimes and other conditions favorable for the population inversion formation and light gain sufficient for laser generation are searched and optimized.

The special strategy of research including the gasdynamic modeling by means of shock tube & supersonic nozzle technique and the photochemical modeling by flash cell technique to understand the behavior of such generator/amplifier laser system are proposed and successfully tested.

The results of pre-laser studies presented show the principal possibilities to develop a new high power laser sources in visible and near IR spectrum for future scientific and technological applications.

[1] Naumov V.V. etc. "Analysis of New Active Media for High Power Gas Flow Lasers in Visible and Near IR Spectrum". LAMP Series Preprint N93/2, ICTP, Trieste (1993).

Experimental investigations of the output beam properties from a high power cw CO_2 laser.

G. Rabczuk, P.Kukiełło, G. Śliwiński

Polish Academy of Sciences, Institute of Fluid Flow Machines,
Fiszera 14. PL 80-952, Gdańsk, Poland

Results concerning the experimental investigations of the output beam propagation properties from a high power, transverse-flow cw CO_2 laser, working in the range up to 1.5 kW, are presented in the paper. The laser output beam characteristics were analysed for two versions of a stable, half-symmetric resonator characterized by the Fresnel number of 1.8 and 2.4 and stability parameters of 0.48 and 0.61, respectively. The resonators considered correspond to the four and three-pass cavity of different optical and active zone length. The beam parameters were measured in the laser processing region, after the beam passing through the 4.3 m in length, three-mirror, optical train closed by the focusing lens of 127 mm focal length.

The scanning knife-edge technique was implemented for measuring the width of the laser beam at various distances from the focusing lens. A clip width (14-86%) as well as the associated scale factor for converting the measured knife position into the second moments width of the laser beam were chosen in agreement with ISO standards. The measurements were performed for two perpendicular (to the propagation axis) directions what allowed to estimate both the assymetry and astigmatism of the beam. Diameters of the focused beam waist, their position as well as the laser beam quality factors were concluded from a hyperbolic fit to the far -field experimental caustic measured for both considered resonators. In the case of four-pass resonator the M^2 parameter was estimated to be abt. 1.8 to 2 while for the three pass resonator the value of M^2, concluded from our measurements, was abt. 2.5 - 3. The far-field divergence values (full angle) of the laser beam were 2 and 3 mrad, respectively.

Oscillation conditions of the laser operation determine the output beam properties and they depend strongly on the resonator configuration. In the case of three-pass cavity characterized by the lower diffraction losses the output beam contains higher order modes than the beam emitted from the four-pass cavity. The analysis of the output beam patterns indicates that the TEM_{00} and TEM_{02}^* modes are mainly responsible for the beam profile from the three-pass cavity while TEM_{00} and TEM_{01}^* dominate when the laser operates with a four-pass resonator.

In the processing range of the laser output power from 0.7 - 1.2kW we do not recorded, the differences in the output beam mode contents, and also no effect of the output power on the measured beam parameters, especially on the M^2 is observed.

Experimental and Theoretical Results of High Optical Quality Excimer Laser Beams

S. Bollanti, P.D. Lazzaro, F. Flora, G. Giordano, T. Letardi,
D. Murra, C. Petrucci, G. Schina, and C.E. Zheng.

ENEA Frascati, INN-FIS-LAC, 00044 Frascati, Italy

In the frame of excimer lasers development program, the ENEA Frascati Research Centre devoted particular attention to the achievement of high optical quality and high brightness laser beams. Two different types of unstable cavities have been mounted on the large aperture ($5x8x100\ cm^3$) HERCULES [1] and the double head IANUS [2] lasers systems. A Positive Branch Unstable Resonator (PBUR) with magnifications M=5 allowed the generation from HERCULES of a rectangular beam with a brightness of $6*10^{13}$ W/(cm^2ster). The IANUS laser system has been equipped on one of its two active media with a Generalized Self-Filtering Unstable Resonator (GSFUR) with magnification M=8. The output beam has a brightness of $8*10^{13}$ W/cm^2ster), with increases up to $3*10^{14}$ W/(cm^2ster) if the beam is injected in the other active medium, used as an amplifier.

In order to analyze the optical quality of these two beams, appropriate near and far field measurements and theoretical calculations have been done. A new hint for the definition of the Times Diffraction Limit ((TDL) of a laser beam comes out from this analysis, relating the TDL to the real beam intensity profile and not to an ideal one (e.g., rectangle or gaussian functions). We obtained for the HERCULES beam a TDL of 13 in one transverse direction and of 17 in the orthogonal one. The GSFUR beam from IANUS was only 1.1 times over its diffraction limit, after amplification, the TDL became equal to 1.6.

A high efficiency soft X-ray laser in the 25-30 nm spectral region

B.Rus et al.
Gas Lasers Department, Institute of Physics, CZ-18040 Prague 8, Czech Republic

The investigation of atomic systems exhibiting lasing action in the soft-X-ray spectral region (i.e. with wavelengths spanning the range from nanometers to tens of nanometers) has been a subject of world-wide effort for about three decades. Since then laser action in the soft-X-ray region has been demonstrated using various inversion schemes, using a laser produced plasma column (obtained by line-focusing a pulsed laser of typically kJ energy) as the active medium. Currently, the X-ray laser is progressively becoming a scientific tool for many new and exciting applications; accordingly, there is a call for easily accessible, small-scale X-ray lasers with wavelengths of the order 20 nanometers, which would require only inexpensive pumping devices and would thus be available to a wide scientific community.

The collisionally pumped X-ray lasers has so far proved the most successful: here, the population inversion is created in a neonlike plasma by electron collisional pumping. This paper first briefly summarises the recent finding that a very weak prepulse applied several nanoseconds prior to the main driving pulse dramatically enhances the intensity of the J=0-1 ($^1S_0$-$^1P_1$) lasing line, improving thereby the pumping efficiency by more than one order. Using this approach, a saturated X-ray laser at a wavelength 21.2 nm was demonstrated[(*)] in neonlike zinc, pumped by an infrared 600 ps-long pulsed laser of merely 350 J of optical energy.

In this paper we propose and thoroughly discus the possibility to use pumping with optimal prepulse conditions (intensity, separation delay from the main pulse) to drive a neonlike X-ray laser for elements between vanadium (Z=23, lasing wavelength 30.5 nm) and iron (Z=26, lasing wavelength 25.5 nm). We will present the results of detailed numerical modelling carried out for slab iron targets, which suggests high gains (up to 7 cm^{-1}) are possible with a driving intensity of $3x10^{12}$ Wcm^{-2}. Assuming a line-focus of 150 μm width and 20 mm length, this implies only ≈30 J in a 400 ps pulse. We will also exhibit the experimental results obtained recently at the laser system PERUN at the Institute of Physics, aimed at complex understanding the parameters of the prepulse-created plasma and suggesting the optimum pumping regime for the next X-ray laser experiments on the aforementioned elements.

(*) Work carried out at Laboratoire de Spectroscopie Atomique et Ionique, Université Paris-Sud, Bâtiment 350, 91405 Orsay Cedex, France

LASER DEPOSITION AND CHARACTERIZATION OF a-C AND a-C:N FILMS

J. Bulíř, M. Jelínek

Institute of Physics, Czech Academy of Sciences, Na Slovance2,
180 40 Prague 8, Czech Republic.

Amorphous a-C and nitrogenated a-C:N films were created by pulsed laser deposition (PLD) under various deposition conditions. Films properties were characterized by spectroscopic ellipsometry, UV-Vis transmission measurements, RBS, Raman scattering; film stresses were also studied.

The experimental setup consists of a KrF excimer laser (EAK, type ELI-94) and vacuum chamber, in which a heating substrate holder is placed in the distance of 3 cm from a graphite target. The laser beam (pulse duration 20 ns, repetition rate 5 Hz) was focused by the quartz lens on the target at an angle of 45°. The target was rotated during deposition. The power density of the beam on the target was $1x10^8$ Wcm^{-2}.

The substrates were optically polished and cleaned in acetone, toluene and ethanol before deposition. At first, the vacuum chamber was pumped out to a pressure of $2x10^{-3}$ Pa by an oil diffusion pump. Before deposition the substrate was heated at temperature 300°C for an hour in order that faster degassing of the substrate surface was reached. After preheating the substrate was cooled near to room temperature or kept on the temperature of 300°C. Films were deposited on quartz or steel substrates in vacuum pressure of $2x10^{-3}$ Pa (a-C) or in nitrogen atmosphere of pressure p_N from 0.5 to 100 Pa (a-C:N).

Ellipsometric measurements performed on the ellipsometer of Rudolph model 436 were accomplished at 5 wavelengths in the spectral range from 400 nm to 800 nm. Measurements were performed for the angles of incidence varying between 50° and 75°. Complex refractive index was fitted to the measured values.

The UV-VIS transmission measurements were carried out on the films using Specord spectrometers 61NIR and UV-VIS.

The intrinsic stress was measured using optical leverage method. The two parallel laser beam were aimed on the substrate and the deflection of the reflected beams was measured.

The amount of nitrogen in a-C:N films increases with increasing nitrogen pressure p_N to 30 percent (RBS analyses). The presence of the nitrogen in the film is confirmed by appearance of the weak peak at 2220 cm^{-1} in the Raman spectra. The increase of p_N is associated with the shift of the G and D peak to the higher wavenumber and with the narrowing of the peaks.

Optical constants of samples exhibit typical behavior of diamond-like carbon in visible region. Refractive index of a-C:N films increases with increasing wavelength in the range from 1.6 to 2.1, extinction coefficient decreases values being between 0.2 - 0.6. The increasing nitrogen pressure during deposition process influences the decrease of the refractive index. Extinction coefficient is higher for higher deposition temperature of the substrate.

The films exhibit good transparency in visible region. The absorption edge of the nitrogen free a-C film is located around 0.4 μm. The increasing nitrogen pressure during deposition process influences a shift of the absorption edge towards to IR region.

The nitrogen free films possess high intrinsic compressive stress. The stress strongly depends on the p_N. With increasing nitrogen pressure the compressive stress around 4 GPa change to tensile stress around 2 GPa. It was found by interpolation of the points that it can be reached a zero stress in a film deposited at a pressure of 1 Pa. In this manner the thick a-C films without buckling and cracking can be prepared. It was also found that previous heating of the substrate enhance the adhesion of the films.

LASER ABLATION AND MODIFICATION OF THIN FILMS

J.Lanèok, M.Jelínek, V. Trtík, L. Jastrabík, CAV, Institute of Physics,
Na Slovance 2,180 40 Prague 8

Advances in the development of high T_C superconducting, diamond like carbon (DLC) and ferroelectric thin films components and device in electronics have led to the optimalization of patterning techniques. The laser patterning has a number of advantage over other techniques. This contribution reports about the process os laser induced etching and ablation of thin films created by pulsed laser depositon.

For films patterning and study of processing parameters a unique workplace was developed consisting of massive microfabrication apparatus with a IBM/PC computer controlled two stepper motors moving in x and y axes, laser triggering and optical monitoring system for visualisation of created structures. As a source of laser radiation a cw Ar^+ ion laser (l = 488-514.5 nm, P = 3 W), and pulsed laser Nd:YAG (l = 1064 nm, t = 10 ns, E_{out}= 7 mJ operated in TEM^{00}) was used.

Measurement of etched profiles were performed using mechanical stylus (Talystep) and the morphology structures was observed by scanning electron microscopy (SEM).The electrical properties of superconductive thin films were measured by the standard four-probe method.

We have studied the influence of laser parameters (regime laser - cw or pulsed, wavelength l, energy and power density, pulse duration t, repetition rate) and optical and thermodynamic parameters of films and substrate material on the physical properties and morphology of generated structures in order to optimalize ablation process. Simple structures as bridges and coils were also created.

The dependence of ablation depth on laser energy density was also studied. From this dependence was determined the ablation thresholds and absorption coefficients for the following films:

YBaCuO/sapphire: ablation threshold 85.3 $J.cm^{-2}$, absorption coeff. $0.6x10^5$ cm-1,
YBaCuO/$SrTiO_3$: ablation threshold 35.1 $J.cm^{-2}$, absorption coeff. $0.55x10^5$ cm-1
DLC/steel: ablation threshold 0.52 $J.cm^{-2}$, absorption coeff. $0.12x10^5$ cm-1.

We have studied the modification of properties YBaCuO/$SrTiO_3$ film in open air atmosphere by focused laser beam for diferent energy density. Film properties were measured by four-point probe method.

The influence of laser patterning on physical properties of superconducting film was also observed. At first the microbridges YBaCuO/$SrTiO_3$ were created. The original film showed a zero resistance temperature TC= 89.2 K and G=2.64 (G is a sloup R(T) function in normal state). Relative degradation T_C and G was studied as a function of width of bridges at room temperature and at 77 K. The degradation of T_C with changing of width was smaller than 1% and independent on film temperature. But degradation of G at room temperature was approximate 20%, opposite to 4% degradation at 77 K.

For patterning by using cw Ar^+ laser it was possible to pattern only YBaCuO layers with laser influence at range 3.0 - 4.0 x106 W/cm2 with the best results a line of 12 mm wide on sapphire substrate.

ANISOTROPIC MELTING OF SEMICONDUCTORS AT IRRADIATION BY POWERFUL LIGHT PULSES

Ya.V.Fattakhov, R.M.Bayazitov, I.B.Khaibullin,
T.N.L'vova, E.A.Eremin
Kazan Physical-Technical Institute of the
Russian Academy of Sciences

The mechanism and the main features of the effect of anisotropic local melting of semiconductor surfaces which can be observed at definite regimes of homogeneous irradiation by powerful pulses of coherent and incoherent light - are investigated.

In spite of intensive studies, up to now, however, the mehanism of this important physical effect and its nature are not understood enough.

As it is known local molten regions (LMR) formed on monocrystalline silicon have definite facets and their shape are unambiguously connected with the crystallographic surface orientation. It is shown that a distortion of the initially regular geometrical shape of the LMRs on implanted silicon depends on silicon surface orientation, implantation fluence, ions type, as well as the duration and the power density of pulse light irradiation.

Studies of the dependence of LMRs density (quantity per cm^2) and sizes on the light pulse duration leading to local melting, were carried out both with fixed value of power density and with its variation from 20 to 2000 W/cm^2. To explain our results we suggest the following model: the formation of a metastable state, characterized by different degrees of semiconductor superheating in the solid phase with respect to equilibrium melting temperature Tm. The value of the superheating ΔT decreases with increasing of light pulse duration (at consequent decreasing of power density of light pulse irradiation).

The processes of local melting of implanted silicon are very complicated because different consequent phase transitions are possible depending on the duration and the power density of the light pulse, as well as on the type of ion, fluence and energy of implantation.

The problem whether the light pulse creates new centres for LMR nucleous formation in addition to existing one was investigated.

Reactive pulsed laser deposition of very hard tungsten carbide thin films

A. LITA, N. CHITICA, Gh. MARIN, M. POPESCU, I.N. MIHAILESCU

Institute of Atomic Physics, Bucharest, ROMANIA

Ch. GRIVAS, A. HATZIAPOSTOLOU

IESL-FORTH, Heraklion, GREECE

We report the successful reactive pulsed laser deposition of very hard and adherent tungsten carbide films on Si wafers. The pure W targets were irradiated in a reactive atmosphere with a Lambda Physik LPX 200 excimer laser operated with Kr-F active mixture (λ=248 nm, τ_{FWHM}=30 ns). The fluence was set at 5 J/cm^2 and the repetition rate at 10 Hz. The reactive atmosphere consisted of CH_4 or C_3H_8, at different pressures in the range of 10^{-4} - 10^{-2} mbar. The substrates were placed parallel to the target, at a distance of 75 mm and the depositions were performed at room temperature. The resulting films are very hard (microhardness values of 2600 Kg/mm^2) and adherent to the substrate. The surface is smooth and a very low number of particulates could be noted. The large target-substrate distance ensured a good uniformity over an area of about 50 x 50 mm^2. A polycrystalline structure with very fine grains was evidenced for all deposited films. These results are very promising for low temperature deposition of hard coatings and for technological application of reactive pulsed laser deposition.

Excimer laser assisted deposition and characterisation of Mo thin films - Fabrication of Mo coatings on optibal fibres

Christos Grivas, Pantelis Papadopoulos, and Argiro Klini
FORTH-IESL, P.O. BOX 1527, GR-71110 Heraklion, Crete, GREECE

The fabrication of molybdenum thin films on quartz substrates using a KrF excimer laser (248nm) is reported. The influence of the substrate temperature (20-400 °C) the energy density (3-10 J/cm^2) and the target-substrate distance (3.5-9cm) on the film properties has been investigated. The surface properties of the ablated layers have been studied by scanning electron microscopy (SEM), atomic force microscopy (AFS), and by microhardness and scratch test.
The excimer laser deposition technique has also been successfully employed for the formation of molybdenum coatings on bare optical fibres. Scanning electron microscope photographs reveal layers with smooth structure, and low droplets density.

IN SULPHUROUS LIQUIDS UNDER ACTION OF SHOCK WAVES

M. I. Markevich, F. A. Piskunov

(Institute of Electronics, Minsk, Belarus)

Laser processing of materials in chemically reactive surrounding mediums has been marked with growing interest. Using a pulsed laser in conjunction with a proper liquid makes it possible to induce rapid and often non - equilibrium reactions at the solid-liquid interface. It is believed that temperature, pressure and phase transformations in the liquid are the key parameters necessary to understand the interface reactions.

The Ni - sulphur containing liquid interface was chosen as model system for the pulsed processing experiments to investigate the effects of pulsed laser processing in different power density regimes, in particular, in circumstances where violent shock waves are generated causing great transient pressures.

It has been proved that the phase composition of the surface products is largely dependent on irradiation power density. Thus, a single NiS phase forms when nickel samples are processed with 1 ms laser pulses of $(1.3 - 3.1)\cdot 10^5$ W/cm^2 power density. The processing of Ni samples with a 50 ns pulse of $4\cdot 10^8$ w/cm^2 power density leads to the formation of an additional Ni_3S_4 phase.

Changes in the phase composition are discussed in connection with the effect of the laser - induced shock wave on the synthesis reaction.

Powerful Gas Lasers With Plasmodynamic Pumping

Yu.S.Protasov

Moscow Bauman State Technical University
107005, MBSTU, Moscow, Russia

The results of R&D, numerical simulation and multiparametric optimization of new class of near IR (1.315-3.79 μm), visible (450-560 nm) and UV (157-342 nm) gas lasers with plasmodynamic pumping and several novel laser systems for advanced projects are presented.

1. Modern trends and new concepts in photochemical industrial systems and laser advanced material processing. Problems and general requirements to lasers, optical robotics and optical contours.

2. The row of high power gas lasers with plasmodynamic pumping on the basis of plasmodynamic high current discharges in gases (direct optical pumping, photodissosiation, pumping with additional chemical reactions, direct photoionization of atoms and molecules, photoionization-recombination pumping). The main physical concepts and classification of plasmodynamic pumping sources. Physical and technological problems, principles of laser modules design, similarity parameters.

3. New photodissosiation lasers tunable in visible (440-550 nm) at low temperature ($T<100$ °C) of active mediums: - trifluoromethyl mercury monohalides: bromide CF_3HgBr, cloride CF_3HgCl, iodine CF_3HgI (B-X electronic transitions). Theoretical analysis of kinetics, main spectral - energetic characteristics, multiparametric optimization of functionally modificated pulse-periodic lasers with long time operation.

A repetitively pulse atomic iodine laser modules ($F'=3 \Rightarrow F=4$) FKG-500, FKG-1000 type with nonmagnetic plasmodynamic pumping and closed circulation of the active (nC_4F_9I - C_8F_{14})-mixtures of thermal type. The comparison of iodine laser sets ($E_g \sim 10^3$J, $\tau_L \sim 25$-35μs, $\theta_r \sim 5 \cdot 10^{-4}$rad, $\lambda_L \sim 1.315$nm) with solid state lasers in technological cycles.

4. Progress in R&D of gas phase laser modules utilizing dihalogenides of metal $Me\Gamma_2$ (Me≡Hg, Cd, Zn, ..., Γ≡Cl, Br, ...), homonuclear molecules of halogens (I_2, Br_2, Cl_2) and interhalogens (visible-UV) with high power optical pumping by wide-band UV-VUV radiation of plasmodynamic discharges directly in active mediums or by radiation of lamp type nonmagnetic cumulative plasmodynamic sources.

5. The results of R&D of the photoionization - recombination near IR laser modules (d-p transitions) exited by the ionizing radiation of polychannel plasmodynamic discharges in active mediums (Ar/Xe-$\lambda \sim 1.73\mu$m, He/Xe-$\lambda \sim 2.03\mu$m, He/Ar-$\lambda \sim 3.79\mu$m). Analyses of kinetic schemes and spectral distribution. Energetic characteristics of the lasers with efficiency at the level of several percent.

6. Radiative gasdynamic processes of laser matter - (solids, liquids, gases and plasmas) interaction in consided spectral - energy range for new applications. Comparison of developed laser's 3D-processing with wide-band thermal radiation processing.

INTENSITY DISTRIBUTION STUDY OF THE LASER BEAM IN RESONANT CAVITIES

Mihaela Enescu, S. Amarande, I. Farcas, C. Vasilescu*
Institute for Atomic Physics, Laser Department
P.O. Box MG-6, RO-76900, Bucharest 5, Romania
*University of Bucharest, Faculty of Physics
P.O. Box MC-11, RO-76900, Bucharest 5, Romania

ABSTRACT

In order to determine the output intensity distribution of the laser beam and the stationary modes of active resonators, we have developed a computer model using the following procedure:

Beginning with an arbitrary amplitude and phase distribution at one of the mirrors (M1) of the laser cavities, field propagation through the resonator is calculated by taking into account the propagation properties of the laser medium and mirror parameters such as: apertures, radius of curvature, transmission coefficient of the output mirror.

After each round-trip the resulting field distribution at mirror M1 is calculated again and compared with that of the previous round-trip. This procedure is repeated until the field distribution reproduces identically after one resonator round-trip, indicating that a stationary mode has been obtained.

Our model is based on the iterative solution of a generalized Kirchhoff - Fresnel integral equation. To get the numerical value of the integral we have evaluated the integral numerically on a two dimensional grid of size N x N. The number of grid points has to be large enough to get a good approximation of the true value. The minimum number N_{min} of grid points is in proportion as Fresnel number.

The cavities of interest for us are characterized by a small Fresnel number and for that case the method require a reasonable computation time.

The computer program was drawn up in the MATHEMATICA language with a modular structure in order to facilitate testing and generalization to the more complex case of resonant cavities with multiple intermediate reflections.

A separate subroutine developed under the same language, makes possible three-dimensional representation of the intensity and phase distribution of the optical (electric) field. Using contour plots, these distributions can be drawn both in the near and far fields. Their evolution can be also evidenced by successive plots taken at any number of iterations.

Preliminary results have been obtained, concerning the influence of laser parameters on out put intensity, phase distribution and mode pattern.

Powerful Gas Lasers With Plasmodynamic Pumping

Yu.S.Protasov

Moscow Bauman State Technical University
107005, MBSTU, Moscow, Russia

The results of R&D, numerical simulation and multiparametric optimization of new class of near IR (1.315-3.79 μm), visible (450-560 nm) and UV (157-342 nm) gas lasers with plasmodynamic pumping and several novel laser systems for advanced projects are presented.

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A repetitively pulse atomic iodine laser modules ($F'=3 \Rightarrow F=4$) FKG-500, FKG-1000 type with nonmagnetic plasmodynamic pumping and closed circulation of the active (nC_4F_9I - C_8F_{14})-mixtures of thermal type. The comparison of iodine laser sets (E_g~10^3J, τ_L~25-35μs, θ_r~$5 \cdot 10^{-4}$rad, λ_L~1.315nm) with solid state lasers in technological cycles.

4. Progress in R&D of gas phase laser modules utilizing dihalogenides of metal $Me\Gamma_2$ (Me≡Hg, Cd, Zn, ..., Γ≡Cl, Br, ...), homonuclear molecules of halogens (I_2, Br_2, Cl_2) and interhalogens (visible-UV) with high power optical pumping by wide-band UV-VUV radiation of plasmodynamic discharges directly in active mediums or by radiation of lamp type nonmagnetic cumulative plasmodynamic sources.

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6. Radiative gasdynamic processes of laser matter - (solids, liquids, gases and plasmas) interaction in consided spectral - energy range for new applications. Comparison of developed laser's 3D-processing with wide-band thermal radiation processing.

Two dimensional temperature measurement using NO multi-line laser induced fluorescence.

Yasuhiro Okada Masafumi Yorozu Akira Endo

INTRODUCTION

Laser induced fluorescence (LIF) technique is very useful for measuring some chemical phenomena. This method has high sensitivity for remote and real time sensing. We applied this technique to measure two dimensional distribution of the temperature in the combustion flame.

TEMPERATURE MEASUREMENT

The nitric oxide (NO) molecules which are in the flame distribute in some different rotational energy states of the same vibration level. The distribution ratio of the rotational states are able to be analyzed by the LIF signal intensity ratios obtained by tuning to the transition lines. With the assumption that the distribution of their rotational states have the Boltzmann distribution, the temperature can be determined.

EXPERIMENTAL APPARATUS

The experimental apparatus was composed with a dye laser pumped by a XeCl excimer laser, an SHG crystal (BBO), cylindrical lenses, a UV filter and an ICCD camera. The dye laser was set around 452nm with 0.5mJ pulse energy, 20ns pulse width and $0.04cm^{-1}$ linewidth. The laser beam was frequency doubled by the SHG crystal and was formed to be a sheet. The fluorescence from the excited NO was detected by the ICCD camera with an f-4.5 lens and a UV filter. The data was acquired to the computer and the temperature was calculated .

RESULT

In the experiments, the transition $A^2\Sigma^+ \rightarrow X^2\Pi$ (0,0) was chosen. According to the Einstein B coefficient, the Q-branch should have the strongest fluorescence intensity so that the Q_1-branch and Q_2-branch were selected. The distribution of the fluorescence intensity with the J-rotational quantum number is shown Fig.1. Fig.2 shows two dimensional temperature distribution using Q_1-branch The distribution by using Q_2-branch looked similar

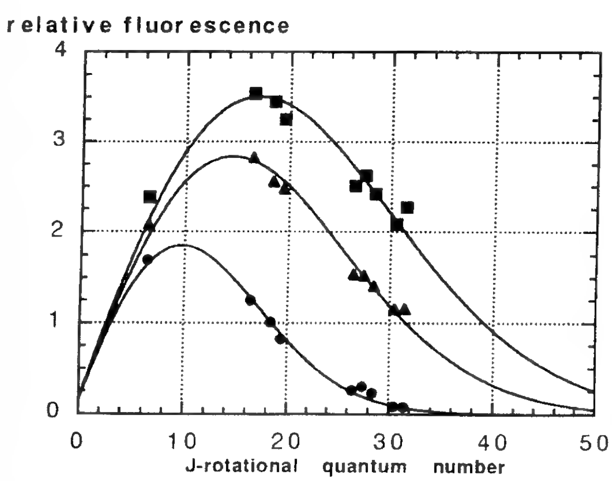

Fig. The distribution of the fluorescence intensity with the

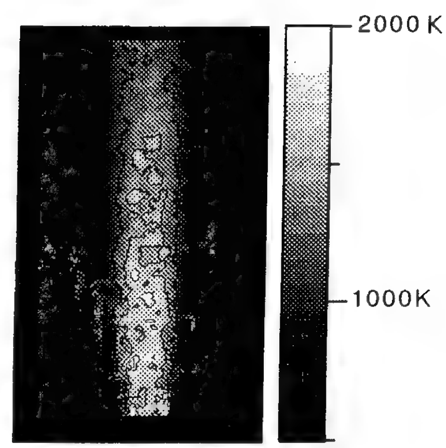

Fig The 2D temperature distribution using Q-

EXPERIMENTAL INVESTIGATION OF SUPPRESSION EFFICIENCY OF LASER INDUCED MEDIUM PERTURBATION IN CO2-LASER.

A.Ageichik, S.Dimakov, I.Kotyaev, A.Safronov, G.Snezhkov, V.Stepanov, A.Rodionov

At present the laser induced medium perturbation (LIMP) effect remains a serious factor, lowering optical quality of high-power CO2 laser radiation. Intensive investigations of this effect have allowed to produce the general recommendations, directed to improvement of radiation angular characteristics of pulsed CO2 lasers. However, efficiency of the use of these recommendations depends on a laser design and its operation mode especially for repetitively pulsed systems because of additional requirements to uniformity of gas flow.

The report presented exhibits some results of investigations on suppression efficiency of LIMP effect in repetitively pulsed CO2 laser by means of three known methods:

-use of gas-mixtures, as active media, enriched with helium and with relatively small percentage of nitrogen,referred in literature
as to "light" mixtures (CO2: N2: He=1:1:6);

-shortening of input pulse duration with the use of conventional so called "heavy" gas-mixtures with helium percentage of approx. 50 %;

-use of cavities with smooth apertured mirrors, shaping a spatially homogeneous radiation--intensity profile.

The experiments were carried out on the electron-beam sustained CO2 discharge laser with active medium volume of 18 liters at pressure of 1-atm. The master oscillator with the unstable confocal cavity with magnification of M=2.7 was designed to utilize a half of the active volume. The output radiation of this master oscillator entered a single-pass amplifier utilizing the second half of the medium.

E-BEAM-SUSTAINED CW CRYOGENIC CO-LASER WITH A SUBSONIC GAS FLOW

A.S.Golovin, V.A.Gurashvily, I.V.Kochetov, V.N.Kuzmin, A.K.Kurnosov, A.P.Napartovich, and N.G.Turkin. TRINITI, nTroitsk, Moscow region, 142092 Russia.

ABSTRACT

The e-beam-sustained cryogenic subsonic gas flow CW CO-laser with radiation power 85 KW, specific output energy up to 100 J/g and efficiency about 30 % at a duration of 5 second is described. The data about spectral structure and beam divergence of output radiation is presented.

Results of theoretical and experimental investigations of the power and spectral characteristics of a e-beam-sustained cryogenic CW CO-laser are submitted, as well as a characteristics of the used for excitation of active laser medium non-self-maintained discharge in mixtures containing of a carbon monoxide. Balance of charged particles and power characteristics of thenon-self-maintained gas discharge in the CO:N2 mixture under pressure 60 - 420 Torr, temperature of 300 K and of a electron beam current density 5 - 40 mcA/cm2 are investigated. The dependence of a recombination factors, frequencies of a electron attachment and part of energy spended in the discharge on direct heating of a gas mixtures containing of a carbon monoxide from parameter Ö/N (E/N is changed from 0.2*10^-16 V*·m2 up to 2*10^-16 V*·m2) are determined and influence of containing in CO impurity F•(CO)5 and Ni(CO)4 on the characteristics of the non-self-maintained discharge is investigated. We have determined if the concentration of carbonyl of Fe and Ni in the gas is exceeding 1 ppm then electron attachment in the discharge is prevailing over the recombination and a electron beam current density necessary for performance of CO-laser is very high.After clearing of a gas mixture from these impurity to concentration smaller 1 ‡‡m the pump energy 300 - 400 J/g at E/N 1*10^-16 V*cm2 was reached at the electron beam current density not exceeding 10 mkA/cm2. Thus the dependence of a recombination factor (beta), frequency of a electron attachment (nua) and part of energy (kappa) spended in the discharge on direct heating of a gas mixture from value of parameter Ö/N may be presented as follow: beta = 8.25*10^-8 (E/N)^-0.851 ·m3/sec; nua= 1*10^4 (E/N)^-0.436 sec-1; kappa = 0.117 + 0.066 ((E/N)-1.71; at calculated dependence of electron drift speed Ud=2.01*10^6 (E/N)^0.702 cm/sec. Experimental e-beam-sustained CO-laser with a cryogenic subsonic gas flow of a mixture CO:N2 = (1:12) - (1:6), the discharge volume of ~ 6 litres, the gas flow speed of 60 - 100 m/sec, gas pressure in a discharge zone of 50 - 100 Torr and temperature of 90 - 150 ä was created. As a gas preionizator electron gun with the high-voltage glow discharge [1] was used which had provided during 5 sec electron beam current density up to 20 mcA/cm2 at the accelerating voltage 130 KV. The active zone was covered by the three-way unstable resonator with a increase coefficient å =1.5 - 2.3. The experiments have shown high efficiency of a created CO-laser. At a pump energy 350 J/g the specific output energy and laser efficiency have exceeded 100 J/gand 30 %, accordingly. The laser radiation power of 85 KW at the duration of 5 seconds had obtained. Investigations of temporary behaviour of a spectral structure and beam divergence of output radiation in the range 50 - 60 KW were performed. The 12 lines of radiation spectrum in the range of waves lengths from 5.145 mcm (transition ê7-6 (11)) up to 5.346 mcm (ê10-9 (10)) contained more than 98 % of output radiation energy are determined and identified.

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THE OPTIMIZATION OF PUMPING REGIMES OF E-BEAM-CONTROLLED CO2-LASER OPERATING ON MIXTURE OF CARBON DIOXIDE WITH ATMOSPHERIC AIR.

B.Yu.Adamiak, A.M.Borodin, A.G.Krasjukov, V.N.Kuzmin, V.G.Naumov, N.G.Turkin, and V.F.Sharkov, TRINITI, Troitsk, Moscow region 142092 Russia.

ABSTRACT

In conditions of large-scale experiment on creation of mobile technological laser complex with target power up to 50 KW the opportunity of achievement of design specific energy input 250 J/g at discharge pulse width to 300 mcsec is shown. At efficiency of 6.5 % the output energy 20 J per pulse is received.

The mobile technological laser complex with target power up to 50 KW is being created at present. The main purpose of this investigation was to prove in conditions of large-scale experiment the opportunity of achievement of design specific energy input of 250 J/g at discharge pulse width up to 300 mcsec and to define experimentally the efficiency of laser generation at various values of ionizing electron beam current density and parameter E/N where E - electric-field strength and N - lasing mixture particle density. To define the optimum regimes of pumping of lasing mixture ëé2 - atmosphere air by non-self-maintained e-beam controlled discharge and to define the conditions of effective generation of powerful laser radiation the single-pulse device was developed and built up. Containing in the lasing mixture air was picked up directly from atmosphere and necessary extra part of stored in a high-pressure cylinder ëé2 was mixed with airthrough reducer. The lasing mixture moved to discharge chamber and then through adjustable throttle mounted on exhaust edge of discharge chamber evacuated in vacuum capacity. The throttle allowed to specify the pressure in discharge chamber and the volume share of ëé2 in mixture was set by means of reducer. As a preionizator the electron gun was used generating the electron beam with current density up to 3 mA/¨2 over area of 200 x 450 mm2 and adjustable pulse width to 300 mcsec. In the discharge chamber was mounted a solid cathode of 270 x 490 ¨2. The output window of e-gun was used as the chamber anode. The distance anod-cathod was 55 mm. The capacitor bank was used as a discharge power supply. The discharge pulse width was specified by e-beam pulse width.
For output of radiation was used three-way stable resonator with the reflection factor of 84 %. The radiation was extract through BaF2 window with transparency of 68 %. The experiments were performed at a fixed flow rate of gas mixture of 0.55 kgs/sec and operating pressure in discharge chamber of 150 Torr. The temperature of mixture was about 293 ä. The volume concentrations of ëé2 in lasing gas mixture was about 5 %. Thus inside the discharge region the follow gas dynamics parameters was provided: the gas density - 0.23 g/l, particle concentration - 0.49*10^19 cm-3, gas flow rate - 78 m/sec. The volume of the discharge region was about 5 l.

The experiments have confirmed the opportunity of achievement of design energy inputs in range of change of a e-beam current density from 0.5 to 2 mA/cm2. However on series of reasons the pumping regime at the e-beam current density of 0.5 mA/cm2 has appeared more preferable as far as in this operation mode the greater value of parameter E/N is achieved that, in turn, increases the share of energy spent on excitation of vibrational levels of molecule N2. It is necessary to note that the operating mode at energy input more than 250 J/g is pre-breakdown regime for all values of e-beam current density. The performed experiments have shown that at gas density of 0.23 g/l, e-beam current density of 0.5 mA/cm2 and pump pulse width of 300 mcsec the specific energy input of 260 J/g may be reached. The radiation output energy of 20 J at efficiency of 6.5 % was obtained.

ON UNSTABLE RESONATORS PRODUCING COMPACT OUTPUT BEAM

N.D. Cherepenin, Yu.Ya. Usanov, Sh.Kh. Zaripov
Kazan State University, Russia

A simple design of an unstable confocal resonator with a continuous rectangular aperture of an output beam was proposed in [1]. In the present report this idea is generalized and unstable resonators with compact output beam for the positive as well as negative branches is considered. These resonators are composed of spherical mirrors and produce the compact output beam by a simple manner, without involving special optical elements. Specific features that provide the compactness to the main part of the laser beam are as follows. First, there is a comparatively small near-axial generation region of the beam along the edge of which an insignificant part of radiation is disposed of. Second, the output mirror is placed with certain asymmetry with respect to the optical axis. The mathematical model of a discharge laser cavity is developed for a fast-flow cw CO_2 - laser. This 3-D model is based on solving the quasi-optical or geometric-optical equations for the radiation field simultaneously with the equations of nonequilibrium gas dynamics and vibrational kinetics for the laser medium. The developed mathematical model includes all the principal design features of the considered cavity. The telescopic and confocal (negative branch) designs of the resonators with rectangular apertures are studied. Space distributions of the resonator lasing modes and the output characteristics of the mentioned laser are investigated numerically. Properties of two considered types of resonators are compared. Numerical simulation allows us to make the following conclusions. Under real operation conditions of a technological CO$_{2}$ laser with the resonators considered here, the electricity-to-light efficiency can be rather high ($\simeq$15\%), the divergence of output radiation being close to the diffraction limit, which is extremely low and corresponds to an ideal rectangular source of radiation. In addition, a part of the output radiation power corresponding to side lobes of its angular distribution proves to be insignificant. This indicates that the proposed resonators with a compact cross section of the output beam are promising better perspectives. The results of numerical simulation allow the optimum design to be chosen for laser devices with such types of resonators.

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Applications of Er and Nd:YAG lasers in ophthalmology and dentistry

H.Jelínková,V.Kubeček,K.Hamal
J.Pašta*,T.Dostálová**

Czech Technical University
Faculty of Nuclear Science and Physical Engineering
Brehova 7,11519 Prague 1,Czech Republic

***Military Hospital**
160 00 Prague 6, Czech Republic

****Institute of Dental Research**
Vinohradská 48, 120 60 Prague 2, Czech Republic

The possibility of using of the high power laser radiation in ophthalmology and dentistry is discussed and analyzed.

Ophthalmology

We report on the selectable Q-switched or mode-locked Nd:YAG (1.06 μm) laser system. Inserting a compact stable oscillator/amplifier system, we increased the output energy in both regimes by a factor of 10-15 (up to 70 mJ), thus allowing to compensate any long term instabilities of the equipment, just adjusting the output attenuator to obtain the desirable energy. The system is used mainly for eye microsurgery - for iridectomy and capsulotomy.

The latest studies indicate that it is possible to use laser radiation for the surgery of anterior segment of the eye. In our study the Er:YAG - ophthalmic laser system delivering 800 mJ maximum energy in 200 μs long pulses was designed and constructed for the experiment of cutting of the cornea tissue (in vitro). From the first results follow that it would be possible to apply the Er:YAG laser radiation in eye surgery - mainly in paracentesis and sclerostomy. Good results could also be reached with therapeutic scleral or corneal ablation.

Dentistry

In our results the optimum cutting of the soft tissue in vivo was achieved with the near infrared radiation from Nd:YAG (1.06 μm and 1.44 μm) lasers. For the hard tissue treatment we developed a new Er:YAG laser dental system which used simultaneously with appropriate water cooling removes enamel and dentin efficiently without causing dangerous pulp temperature changes. The results of our studies demonstrate the feasibility of the pulsed Er:YAG laser in stomatology.

List of Participants

Prof. Sergei Anikichev
3000 Bathurst St, 1205
North York Ont M6B 3B4 Canada

Prof. Taner Bulat
Physics Department
Istanbul University
Vezneciler
34459 Istanbul Turkey

Dr. Nicolae Chitica
Lasers
Institute of Atomic Physics
P.O.Box MG-6
RO-7690 Bucharest Romania

Dr. S A. Dimakov
Vavilov State Optical Institute
12 Birzhevaya
St. Petersburg, 199034 Russia

Ms. Mihaela Enescu
Lasers Department
Institute of Atomic Physics
P.O.Box MG-06, Magurele
76900 Bucharest 5 Romania

Dr. Yakh'ya V. Fattakhov
Radiation Physics Laboratory
Kazan Physical Technical Inst.
Sibirski Trakt 10/7
Kazan Tata 420029 Russia

Prof. Maria J. Gomes
Deprtment of Physics
University of Minho
Largo do Paco
4709 Braga Portugal

Dr. Krassimir A. Grozdanov
Institute of Electronics
72 Czarigradsko Shose Blvd.
1784 Sofia Bulgaria

Dr. Wolfgang Hackenberg
Max Plank Institute
fur Extraterrestische Physik
Giessenbachstrasse
D-85740 Garching Germany

Dr. Sarah Bollanti
INN-FIS-LAC
ENEA
P.O.Box c5
00044 Frascati (Rome) Italy

Mr. Jiri Bulir
Institute of Physics
Czech Academy of Science
Na Slovance, 2
18040 Prague 8 Czech Republic

Dr. Vitaly V. Datsyuk
Physics Department
Kiev T. Shevchenko Univ.
64 Vladimirskaya Street
Kiev 252017 Ukraine

Prof. Hans J. Eichler
Optisches Institut
Technische Universitaet Berlin
Str. des 17. Juni 135
D-10623 Berlin Germany

Dr. Aslam Farooq
Nat'nl Inst. of Silicon Technology
H. No 942 St 29, G-9/1
Islamabad Pakistan

Dr. Bernard Forestier
Institute of Fluid Mechanics
Universite d'Aix-Marseille II
1 Rue Honnorat
13003 Marseilles, France

Dr. Christos Grivas
Inst. Electronic Struct. & Physics
FORTH - Hellas
P.O.Box 1527, Vassilicka Voutou
71110 Heraklion Greece

Mr. Eniko E. Gyorgy
Lasers
Institute of Atomic Physics
P.O.Box MG-6
RO-7690 Bucharest Romania

Mr. Alexandru Hening
Lasers Div.
Institute of Atomic Physics
P.O.Box MG-21
RO-7690 Bucharest Romania

Prof. Geoffrey P. Hogan
Laser Group
Oxford University
Clarendon Lab., Parks Road
Oxford, OX1 3PU UK

Dr. Borislav L. Ivanov
Dept. of Semiconductors
Higher Inst. Chemical Technol.
8 Kl. Ohridski Street
1756 Sofia Bulgaria

Dr. Helena Jelinekova
Nuclear Sci. & Physics Dept.
Czech Technical U.
Brehova 7
115 19 Prague 1 Czech Republic

Dr. Konstantin P. Komarov
Solid State Lasers
Inst. Autom. and Electrometry
Universitetskii Pr. 1
Novosibirsk 630090 Russia

Dr. Hanita Kossowsky
Emerging Technologies, Inc.
6327 Burchfield Avenue
Pittsburgh PA 15217 USA

Dr. Ariadna S. Kozlova
Physics Department
Moscow Aviation Institute
Volokolamskoye Shosse, 4
Moscow 125871 Russia

Dr. Victor Kuz'min
Troitsk Institute
Moscow Region
142092 Troitsk Russia

Dr. Shimon Lavi
Lasers Department
DDR&D - MAFAT
Hakirya
Tel Aviv Israel

Dr. Paul Lovoi
Internat. Tech. Associates
2281 Calle de Luna
Santa Clara, CA 95054 USA

Mr. Athanasios Ioannou
Physics Department
University of Patras
26500 Patras Greece

Prof. Miroslav Jelinek
Physics Institute
Czech Academy of Science
2 Na Slovance
18040 Prague 8 Czech Republic

Mr. Andronikos Kakkouras
EEE Optoelectronics Div.
University of Strathclyde
204 George Street
Glasgow G1 1XW UK

Dr. Ram Kossowsky
Emerging Technologies, Inc.
6327 Burchfield Avenue
Pittsburgh PA 15217 USA

Dr. Lyudmila Kotomtseva
Institute of Physics
Belarus Academy of Science
70 F. Skarina Ave.
220072 Minsk 1 Belarus

Dr. Alexander Kubishkin
NICTL RAN
Scientific Res. Cntr., Lasers
Svyatoozerskaya 1
Shatura, Moscow 140700 Russia

Dr. Bernard Lacour
Lasers Department
Laserdot Corporation
Rue de Nozay
91460 Marcoussis France

Dr. Alexander V. Lavrov
Deputy Laboratory Chief
Russ. Scien. Ctr. Appl. Chem.
14 Dobrolubov Ave.
St. Petersburg 197198 Russia

Dr. Antonio Lucianetti
Faculty of Physics
European Laser Engineering
Via Borgo Palazzo 90
24100 Bergamo Italy

Prof. Alexander M. Manenkov
General Physics Institute
38 Vavilova Street
Moscow, 117942 B-333 Russia

Ms. Maria Markevich
Physics of Thin Films Dept.
Belarus Institute of Electronics
22 Logoiskij Tract
220841 Minsk Belarus

Dr. Peter Mraz
Avantek, s.r.o.
Mierove nam. 11
915 01 Trencin Slovakia

Mr. Thomas R. Nelson
Physics Department
University of Illinoise
M/C 373, 845 W. Taylor, Rm 2136 SES
Chicago IL 60607-7059 USA

Dr. Yasuhiro Okada
R&D Center, Optronic Group
Sumitomo Heavy Industries, Ltd
63-30 Yuuhigaoka,
Hiratsuka Kanagawa Japan

Prof. Peter Persephonis
Physics Department
University of Patras
26500 Patras Greece

Dr. Kirill Prokhorov
VKIV
General Physics Institute
Vavilov Street, 38
Moscow 117942 Russia

Mr. Grazyna Rabczuk
Institute of Fluid Mechanics
Fiszera 14
Gdansk Poland

Prof. Amedeu L. Rodrigues
Department of Electrical Engineering
New University of London
DEE-FCT/UNL
2825 Mont de Caparica Portugal

Mr. Genrikh Sh. Manukyan
Min. Atom
Efremov Research Institute
Sovetski Avenue 1
St. Petersburgh 189631 Russia

Prof. Vladislav Moshkov
Baltic State Technical Univ.
1 First Krasnoarmeyskaya St.
St. Petersburg, 198005 Russia

Dr. Vadim V. Naumov
Photoactivity Department
Institute of Physics
46 Prospect Nauki
Kiev 252650 Ukraine

Dr. Maxim Novgorodov
Optics Department
Lebedev Physical Institute
Leninsky Prospect, 53
Moscow 117924 Russia

Dr. Nicolaie Pavel
IFTAR-MALIRM
Institute of Atomic Physics
P.O.Box MG-6
76900 Bucharest Romania

Dr. Ladislav Pina
Physical Electronic Department
Czech Technical University
V Holesovickach 2
CZ-1800 Prague, 8 Czech Republic

Dr. Yuri S. Protasov
Bauman State University
2 Bauman Street
Moscow 107005 Russia

Dr. A Yu Rodionov
Vavilov State Optical Institute
12 Birzhevaya
St. Petersburg, 199034 Russia

Dr. David Roessler
Research & Environmental Staff
General Motors
30500 Mound Road, Bldg. 1-6
Warren, MI 48090-9055 USA

Dr. Bedrich Rus
Department of Gas lasers
Institute of Physics
CZ-1804 Prague, 8 Czeck Republic

Dr. Vladimir Shashkov
Troitsk Institute
Moscow Region
142092 Troitsk Russia

Prof. Nikolay I Shentsev
Insti., Physics & Technology
Ozernay 10-12, Sergiev Posad 7
Moscow 141300 Russia

Prof. Viktor F. Tarasenko
Siberian Division
High Currents Electronic Inst.
4 Akademichesky Ave.
Tomsk 634055 Russia

Prof. Octav Teodorescu
Department of Physics
University of Bucharest
C.P. 22-90
Bucharest Romania

Dr. Keith Truesdell
PL/LIDB
Philips Laboratory
Kirtland AFB
Albuquerque, NM 87117 USA

Prof. Miroslava Vrbova
Physical Engineering
Czech Technical U.
Brehova 7
115 19 Prague 1 Czech Republic

Prof. W. J. Witteman
University of Twente
P.O.Box 217
7500 AE Enschede, The Netherlands

Mr. Yuri N. Zavalov
NICTL
Scientific Research Cntr., Lasers
Svyatoozerskaya 1
Shatura, Moscow 140700 Russia

Mr. Denis Saraev
Russian Materials Science Cntr.
Tomsk State University
2/1 Akademicheskii Av.
Tomsk 634055 Russia

Dr. Valentin Shekhtman
Director
Engineer. Physical Laboratory
Pushkin 8, Box 260
St. Petersburg 189620 Russia

Dr. Ian Spalding
FS/141
AEA Technology
Oxfordshi Culham, Abington OX14 3DB UK

Dr. John R Taylor
Optical Systems Group
Lawrence Livermore N.L.
P.O.Box 5508, L-462
Livermore, CA 94550 USA

Mr. Vitezslav Trtik
Institute of Physics
Czech Academy of Science
Na Slovance, 2
18040 Prague 8 Czech Republic

Dr. Igor A. Tumanov
Min. Atom
Efremov Research Institute
Sovetski Avenue 1
St. Petersburgh 189631 Russia

Dr. Robert F. Walter
W.J. Schafer Associates, Inc.
2000 Randolph Road, SE
Albuquerque NM 87106 USA

Dr. Shamil K. Zaripov
Department of Gas Dynamics
Inst. Mathematic & Mechanics
Kazan State U,, Universitetskaya 17
Kazan Tart 420008 Russia